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Science and Scientist

The future of civilization is well-nigh in your hands. Those of us who represent social organization and political institutions look upon you with something of fear, as we ask ourselves to what revolution you will next require us to adapt our scheme of human relations. But we know you are animated by a profound purpose to better the estate of men.

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Science knows no political boundaries, she recruits her conquering chieftains from all climes and races. In this field all are co-workers and pride is not of race or of traditions but of achievement in the interest of humanity.

CHARLES EVANS HUGHES

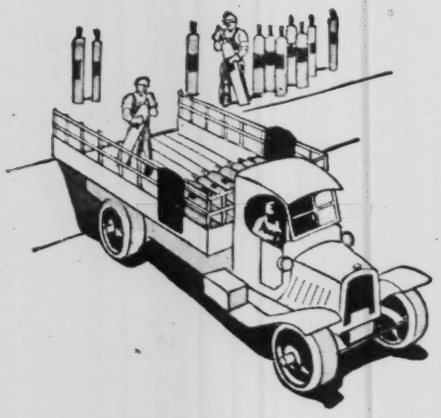
(Extracts from addresses to the A.A.A.S.)

FEBRUARY 1925

THE MONTHLY JOURNAL PUBLISHED BY THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

"This phase of our service will be recognized"—

wrote a vice-president of the Linde Company six years ago



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Mechanical Engineering

The Monthly Journal Published by

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Volume 47 February, 1925 Number 2

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H. G. Barnhurst

W. M. McFarland

H. N. Davis

F. G. Keyes

N. S. Osborne

H. W. Brooks

Contributors to this Issue

W. F. Durand, author of the leading article in this issue on The Problem of the Colorado River, is a scientist and consultant of international prominence in the field of mechanical engineering. While he has specialized largely in hydroelectric development, he has also taken an active part in the development of aeronautics and marine engineering. In 1918 and 1919 he was Scientist Attaché at the American Embassy in Paris and was a member of the Inter-Allied Committee on Inventions.

Since 1909 Dr. Durand has been a member of the Board of Consulting Engineers for the City of Los Angeles in connection with the development of hydroelectric power in that city along the line of the Los Angeles aqueduct. This work was in connection with their proposed participation in the Boulder Cañon project on the Colorado River.

* * * * *

Walter M. McFarland, whose address on Admiral George Wallace Melville is included in this issue, is manager of the marine department of the Babcock & Wilcox Co., New York. He was graduated from the United States Military Academy in 1879 and until 1899 was in active service, the last four years of which he served as assistant to Admiral Melville. At the end of that period he became vice-president of the Westinghouse Electric & Manufacturing Co. Since 1910 he has been associated with the Babcock & Wilcox Co. During Mr. McFarland's career he has served as assistant professor and lecturer in engineering at Cornell University. He is a past vice-president of both The American Society of Mechanical Engineers and the Society of Naval Architects and Marine Engineers; he is also a member of the American Society of Naval Engineers.

* * * * *

H. G. Barnhurst, who presents in this issue a paper on The Preparation of Pulverized Coal is advisory engineer for the Fuller-Lehigh Co., Fullerton, Pa. Mr. Barnhurst was born in Philadelphia, Pa., and is a graduate of Haverford School. He served an apprenticeship with the Humboldt Iron Works, Pa., and then was associated for short periods with the Union Iron Works, the Erie City Iron Works, the Ball Engine Co., the Atlas Portland Cement Co., Cambria Steel Co., and the Lehigh Portland Cement Co. In 1906 Mr. Barnhurst became chief engineer of the Fuller Engineering Co., Allentown, Pa., which position he held until 1912 when he was appointed advisory engineer of the Fuller-Lehigh Co.

* * * * *

H. W. Brooks, in charge of fuel investigations, U. S. Bureau of Mines, contributes an Historical Outline of the Development of Pulverized Coal as a Boiler Fuel, as well as a report on Outstanding Developments in Fuels Engineering and Research during 1924. He was graduated from Cornell University in 1911 and then spent five years with the Westinghouse Electric & Manufacturing Co. Subsequently he engaged in consulting and construction engineering in the United States and Latin America. During the war he served first as mechanical engineer for the War Department and later for the the Navy in charge of the Ordnance Machinery Section. He was appointed American delegate to the World Power Conference in London in the summer of 1924 and afterwards made for the Bureau special investigations of fuels utilization in nine European countries.

* * * * *

At the Steam Table Research Session of the last Annual Meeting of the American Society of Mechanical Engineers there were presented six reports. **Geo. A. Orrok,** who reported on general progress is chairman of the Steam Table Research Fund Executive Committee and is a consulting engineer of New York City. **R. V. Kleinschmidt,** who presents the report on the Harvard experiments, is a Fellow for Research at Harvard University. **F. G. Keyes,** who reports on the progress of the work at the Massachusetts Institute of Technology, is connected with the Research Laboratory of physical chemistry at that institution. **N. S. Osborne** and **H. F. Stimson,** who together report on the progress of the work at the United States Bureau of Standards, are both associated with the Bureau, Dr. Osborne being physicist. **Harvey N. Davis,** who writes on the Joule-Thomson Effect, holds the chair of mechanical engineering at Harvard.

* * * * *

Magnus W. Alexander, who writes on Industry's Interest in Industrial Training, the account of the Session on Education and Training for the Industries is managing Director of the National Industrial Conference Board. **Frank Cushman,** author of District Organization of Modern Apprenticeship at the same Session, is chief of the industrial education service, Federal Board for Vocational Education; and **H. A. Frommelt,** who contributes the article on Training for Industry and the Public Program of Vocational Education is apprentice superintendent of the Falk Corporation.

* * * * *

F. J. Schlink, author of a paper in this issue on Classification of Engineering and Industrial Standards, is assistant secretary of the American Engineering Standards Committee, New York. Mr. Schlink has received the degrees of B.S. and M.E. from the University of Illinois. He was formerly associated with the United States Bureau of Standards which he entered in 1913 as laboratory assistant in engineering, later becoming assistant and then associate physicist in charge of the Information Section.

Important January Meetings at Cleveland and Chicago

On January 13 there was held in Cleveland an all-day conference on Steam-Production Economies. Mr. Wolff's paper at this conference on Test of Pulverized-Fuel-Fired Boilers at Lake Shore Station, Cleveland, was published in the January issue of MECHANICAL ENGINEERING while Mr. Barnhurst's and Mr. Brooks' papers at the same meeting appear in this issue.

The second annual power meeting of the Chicago Section was held on January 14 and 15 with the first day devoted to a most interesting technical program and the second to visits to near-by plants. It is planned to present the main technical features of this meeting in our next issue.

MECHANICAL ENGINEERING

Volume 47 February, 1925 No. 2

The Problem of the Colorado River

Removal of the Flood Menace to Imperial Valley—Need for an Abundant Water Supply in the Southwest for Municipal and Irrigation Purposes—The Proposed Boulder Cañon Dam and Reservoir Site—Hydroelectric Power Development

By WILLIAM F. DURAND,[1] STANFORD UNIVERSITY, CAL.

THE problem of the Colorado River takes form around four basic facts or sets of conditions. In this sense it may be considered as quadrangular in character. These sets of conditions are as follows:

1 The actual present development in the Imperial Valley and the menace under which it exists of destruction by flooding from the Colorado River

2 The need of an abundant and reliable supply of water for municipal and domestic purposes and the absolute limitation which such supply places upon the increase of population and the advance of civilization, especially in the southwestern part of the United States

3 The existence, in the states comprising the Colorado River watershed, of some 4,000,000 acres of land, now barren and unfruitful, but susceptible of irrigation from the river and thus admitting of transformation into rich and fruitful land

4 The always-increasing demand in the Southwest, and especially in the southern part of the state of California, for electric power, the present magnitude of this demand, its rate of increase and probable growth during the next few decades.

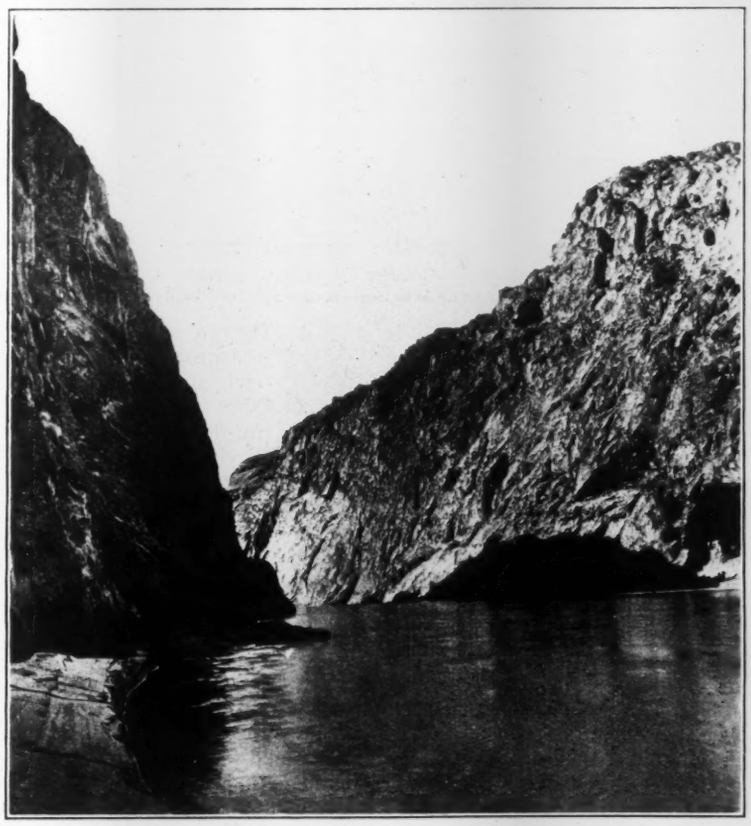
The Four Aspects of the Problem

Let us consider first, for a moment, the present development in the Imperial Valley. This is a section of the southern part of the state of California dependent solely for its existence on irrigation from the Colorado River. The present population of the Valley is approximately 70,000 and the number of acres under irrigation about 500,000. The investment cannot be stated in monetary terms. The inhabitants of that Valley, reclaimed from the desert, have invested not only their money but their lives, their homes, their labor, their all. And a large part of this great and fruitful area lives in constant menace of destruction by overflow from the Colorado River.

In common with all such great silt-laden streams flowing through a silt-formed delta to the sea, the river is constantly tending to build up its bed and shift its course. These natural physical processes have gone on until in the course of years the Colorado River has built up its bed and its banks to an elevation far above the level of much of the land adjacent, and especially above large areas in the Imperial Valley which are in part below even the level of the sea. As will be remembered, a serious break and a partial flooding of the valley occurred in 1904–1905 and damage running into the millions resulted and millions more were spent before the break was closed. Unusual flood conditions at any time may, seemingly, bring about a recurrence of such disaster. It is a situation which calls most emphatically for correction. These pioneers of a newly reclaimed and fruitful valley have a right to hope for some control of the river which will enable them to face the future without the apprehension of total destruction through an overflowing Colorado River.

Turning next to the problem of water supply, it is, perhaps, fair to say that those who live in parts of the country with plentiful rainfall, that is, with an annual precipitation of 25 or 30 inches and more, are not likely to be able to realize the rigid dependence of advancing civilization on water supply and the gravity of the menace to large centers of population through a threatened limitation or shortage in such supply. In particular, the situation in the city of Los Angeles may be briefly indicated.

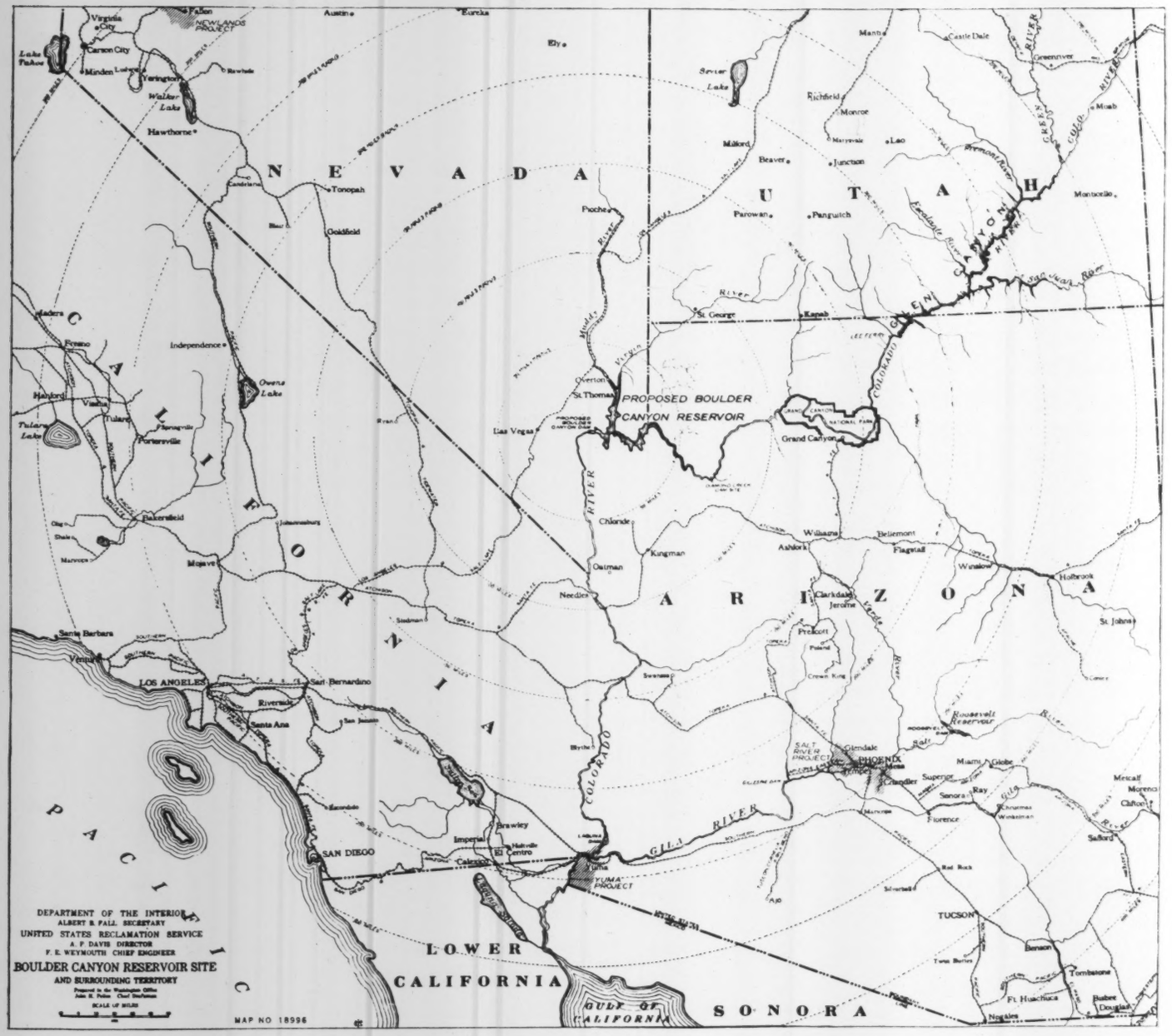
About twelve years ago the Los Angeles Aqueduct was completed and opened for service to the city. This was planned as an adequate supply for a city of 2,000,000 inhabitants. Due to a shortage of rainfall in the period since completion, to some legal difficulties in connection with water rights in the Owens River watershed, and to other minor causes, the full flow of the aqueduct has not as yet been realized, and it is not sure that the present sources can be depended on for a city of the size originally contemplated. In the meantime the city has grown to and beyond the million mark and, with the present rate of growth, will in a few years be dangerously near the limit of water supply from present sources. Large water-supply systems, furthermore, are not designed and constructed over night, or in a year or in two or three years. Engineering works of this character and order of magnitude require many years for their



Black Canon Dam Site Looking Downstream

[1] President A.S.M.E.

Address delivered at a luncheon meeting of the Philadelphia Engineers' Club, December 9, 1924, and published also in *Engineers and Engineering*.



BOULDER CANON RESERVOIR SITE AND SURROUNDING TERRITORY
(Dotted circles showing distances from dam site increase in radius by 50-mile steps from center.)

realization, and from the present situation, as outlined above, it is clear that the city of Los Angeles can afford to lose no time in the investigation and planning of an enlarged municipal water supply.

Regarding desert land available for and susceptible of economic irrigation from the Colorado River, it is a simple fact of survey that there are some 4,000,000 acres not now under cultivation—about 2,500,000 in the upper or mountain division of the river and its tributaries and 1,500,000 in the lower or so-called desert division—which might be made fruitful and food producing by turning upon them the waters of the Colorado River which now runs to waste into the sea.

Regarding the growing demand for electric power, little need be said before an audience of engineers. It will not be easy, however, for those who have not been in personal contact with the situation in the new Southwest to realize the rapidity of the growth and the magnitude of the prospective demand at a time no more than five years distant. Such demand, over and above the probable supply from sources in the neighboring mountains, is measured in terms of hundreds of thousands of horsepower. If hydroelectric power is not to be supplied from the Colorado River, it seems sure that the two following conditions will promptly develop—especially in Los Angeles and the surrounding and contiguous territory:

1 The rate of development of power will lag distinctly behind the growth in demand, thus hampering and restricting civic growth, especially along industrial lines
2 Effort will be made to meet the demand, so far as may be, by developments in the Sierra Nevada Mountains relatively small in individual size and many in number, or of especially difficult and costly character—all making for relatively costly power and thus likewise imposing restriction on civic growth along industrial lines.

The ever-insistent demand is for power in quantity and at low rates, and no source or combination of sources aside from the Colorado River can for long adequately meet this demand.

THE COLORADO RIVER AND ITS CHARACTERISTICS

Let us now turn to a brief survey of the Colorado River and its characteristics, in order to see in what manner it may be made to fit in as the key to this quadrangular problem.

I would first ask you to picture this river formed, so far as the name goes, in southern Utah by the junction of the Green and the Grand and flowing thence approximately 1000 miles to the sea. If, however, we trace the larger of these two, the Green, back to its source in Wyoming, we find a total length from source to outlet of

about 1700 miles, running through and between five states, receiving along its way numerous affluents and with a total watershed of some 240,000 square miles. It has been found convenient to consider this great territory tributary to the Colorado River under three subdivisions:

1 The upper or Mountain Division
2 The Cañon Division
3 The lower or Desert Division.

The first of these includes the Rocky Mountains section drained by the Green and Grand and upper tributaries generally down to their junction in the Colorado River proper.

The second division, extending from the Green and Grand junction westward to and around the elbow along the southern boundary of Nevada, includes the Marble, Grand, Boulder, Black and other minor cañons.

The third division includes that part of the river which lies between California and Arizona, and thence on through Mexico to its outlet in the Gulf of California.

The average gross annual discharge of the river is some 16,000,000 or 17,000,000 acre-feet, varying considerably on either side of such mean figure according to seasonal conditions. The mean rate of flow corresponding is some 22,000 second-feet. The minimum flow in the late fall may drop to a quarter of this amount and the maximum flow in flood periods may rise to ten times this figure or upward of 200,000 second-feet.

The flood conditions in the Colorado River develop in the spring as a result of spring rains and melting snow. The flood period may extend over 60 to 100 days, usually reaching its peak in June. The total discharge during such a flood period may vary between wide limits from a moderate or small flood of four or five million acre-feet up to a heavy flood of twelve to fifteen million acre-feet. These conditions, as stated, refer especially to the Colorado River proper or to the Colorado above the inlet of the Gila near Yuma. The latter river is subject to floods of extreme peak value—approaching or equaling those of the Colorado itself, but of relatively short duration and with a correspondingly small total volume of discharge. Such floods may occur irregularly through the year, due as they are to cloudbursts and torrential rains, but rarely during flood conditions in the river proper. So far as menace to the Imperial Valley is concerned, the chief danger is from the long-sustained flood of the river proper with always the possibility of some sudden augmentation from conditions in the Gila watershed.

Another feature of importance in the flow of the river is the silt burden. This has been estimated by the engineers of the Reclamation Service at from 80,000 to 100,000 acre-feet per year.

Removal of the Menace to Imperial Valley—The Boulder Cañon Dam and Reservoir Site

Now with this brief picture of the river as a physical entity, let us consider the way in which it may lend itself to the solution of the problems previously noted.

In the first place, it should be observed that the menace to the Imperial Valley arises from two conditions:

1 The silt burden which is laid down in the lower stretches of the river just below the California line, and in consequence of which it is constantly building up the level of its bed and banks, thus raising the actual river level above that of the surrounding land
2 The possibility of unusual floods which may overtop the present river borders, cut great channels through the light silt banks, and submerge the surrounding land.

Relief from this menace is seen to depend upon two conditions:

1 Reduction of the amount of silt carried by the river, and thus of the rate of uplift of the river channel

Boulder Canon Dam Site Looking Downstream

2 Control of the river during the flood period and a limitation of the maximum flow to an amount which can be safely carried by the channel.

It is obvious that both of these conditions can be met by a suitable dam and storage reservoir at some point on the river, naturally in the cañon division.

The best location for such a dam, taking all considerations into account, is still a matter of debate among those having contact with the problem and I shall not enter into this controversial phase of the question. The general character of the problem and the possibilities of its effective treatment will, however, be admirably illustrated by assuming such dam and reservoir to be located at the so-called Boulder Cañon site. This site in point of fact offers two available locations for a dam, one at Boulder Cañon proper and the other some 12 miles down the river at Black Cañon. In either case the reservoir site, its capacity and extent would be substantially the same.

Speaking then of this general locality as the Boulder Cañon site, it appears to be entirely feasible to build, in a narrow cañon, a dam 550 or 600 feet above present mean low-water level, or roughly 650 to 700 feet above bedrock in the channel bottom, and thereby to impound from 25,000,000 to 31,000,000 acre-feet of water.

I speak of this range of possibilities not as restrictive but as indicating that study of the various elements entering into the problem seems to indicate a solution in the neighborhood of these figures.

Time will not permit of any detailed consideration of the technical questions entering into the design of the dam or its appurtenant structures. It must suffice to say that there is abundant engineering opinion based on careful exploratory work and supporting the project as one entirely feasible from the engineering point of view.

It may be of interest to note the magnitude of the reservoir which it is thus proposed to create. The three largest similar reservoirs in the world at the present time are the Assuan reservoir, the Roosevelt reservoir, and the Arrowrock reservoir. These are each of the general order of 2,000,000 acre-feet, so that the reservoir proposed at Boulder Cañon would take all three of the reservoirs named four or five times over.

Having also in mind the twelve to fifteen million acre-feet of total discharge of the normal heavy flood, it is clear that with the reservoir brought to half-capacity level at the beginning of a flood period, the entire flood discharge could be held in the reservoir without overtopping the dam. This, of course, is not necessary nor is it desirable. It is again readily seen that with no more than normal average river flow, the discharge during a 100-day flood period would aggregate about five million acre-feet, leaving only the balance of seven to ten million to be taken care of by the reservoir. But there is no reason for any such limitation of the river flow below the dam. All observation and available data show that a maximum discharge of two or even three times the average may be contemplated with complete confidence of security; and with such a permitted maximum discharge the safety of the Imperial Valley seems to be as definitely assured as anything can be which depends on the phenomena of nature. On this particular point a large number of detailed studies have been made, comprising a day-by-day study of the river with assumed discharge facilities through the dam, and it has been clearly shown that with facilities such as are clearly within the scope of present engineering practice, and assuming the daily pattern of the most serious flood of which there is a definite record, the daily discharge can always be held never to exceed any desired safe upper limit such as fifty, sixty, or seventy thousand second-feet, and with a total rise in the general reservoir level of perhaps not to exceed fifty feet.

In short, then, the provision of such a dam and such a reservoir furnishes a complete answer to the problem of the present menace to the Imperial Valley.

It may naturally be asked at this point, having in mind the figures just given, whether a reservoir of this capacity is needed, so far as the protection of the Imperial Valley from flood menace is concerned. The answer is, no, it is not required. A reservoir of capacity of ten, twelve, or fifteen million acre-feet could be made to provide all needed security for the Imperial Valley. The justification for the larger capacity does not lie in the needs of the Imperial Valley but rather in the problem of meeting the requirements for electric power and of providing a safe economic foundation for such an undertaking through the sales of such power.

This may also be an appropriate point to refer to the matter of silt. Obviously with a reservoir of twenty-five to thirty million acre-feet capacity and with a surface area of some 150,000 acres, the silt-bearing Colorado, as it enters such an expanse of water, will drop its silt burden. This will mean the inevitable accumulation of silt in the reservoir, and if the entire silt burden of the river were to be thus deposited in this one reservoir the ultimate result would be its complete obliteration and destruction for the purposes intended. In this connection, two facts are to be considered:

1 The lower 5,000,000 acre-feet of capacity in the reservoir as proposed are considered as a silt pocket rather than as active water storage. All plans for the operation of the reservoir disregard active use of this lower stratum of volume. On the basis of the estimates of the Reclamation Service of a silt burden in the Colorado River proper of eighty to ninety thousand acre-feet per year, it is clear that the capacity so reserved should serve for a period of some sixty years.

2 The Boulder Cañon site is only one of a number of reservoir sites which are available and suitable for such purposes and of which future years will certainly bring the utilization. With such a condition in effect, a part only of the silt burden will be deposited in any one reservoir and the day of the ultimate obliteration of such a chain of reservoirs is thus relegated to a future so far removed as to be of small present significance. In any case and even if such a chain of reservoirs should be doomed to ultimate obliteration, the benefits to be received in the meantime would nevertheless abundantly justify their construction and use. The ultimate solution of the situation which may present itself after a period of several hundred years may, perhaps, be safely left to the eminent engineers who will arise in those later days.

These considerations regarding silt accumulations furnish likewise a further argument for the larger capacity of reservoir rather than the smaller.

WATER SUPPLY FOR IRRIGATION AND MUNICIPAL USE

Turning now to the problem of water supply, it is obvious that the water is there in superabundance and is now running to waste into the sea. When we remember that a continuous flow of 200 second-feet is sufficient to provide a liberal water supply for a city of 1,000,000 population, and when we remember that the mean flow of this river is more than 100 times this amount, the magnitude of the supply in comparison with human population is plainly apparent. We cannot forget, however, that in general the demands for irrigation and for municipal supply are in direct competition and that only in some small degree can the water used for the former be made available for the latter. In particular is it true that water used for irrigation on the lands normally tributary to the Colorado River cannot be made available for municipal use in the central and western areas of the southern part of California—that is, in those parts in which the available supply of potable water is most likely to stand as a limitation to the now rapidly expanding populations.

While, therefore, there must ultimately, perhaps, be some choice as between these two uses of water, it is clear that very large populations might be provided with water from the river while still leaving by far the larger portion available for use on irrigated lands. It seems also fair to forecast that the need for municipal supply will become urgent, even imperative, long before that for large increase in irrigated lands. In brief, the need of water for municipal supply seems likely to be the more immediately pressing of the two, and so long as no large inroad is made on the total supply it would seem clear that there should be no hesitation in its appropriation to such use.

In order to realize such use—in order to deliver Colorado River water to the cities of southern California—three major problems must be solved. These are:

1 The water must be cleared of its silt by settling

2 According to the best routes so far developed by preliminary survey, the water must be lifted, by pumping, some 1000 or 1200 feet in order to pass it over the range of

mountains lying between the river and the territory which it is to serve

3 A waterway, with suitable branches and comprising canal and tunnel sections, must be provided between the river and the storage reservoirs near the points of consumption.

The solution of the first problem is found in a large storage reservoir such as that at Boulder Cañon. Here the silt will be deposited, and the water rendered substantially clear. The actual point of intake would be at a point some miles below the cañon where a low dam would provide for a second settling before passing into the aqueduct waterway. If further settling is required it can be provided by local and smaller reservoirs.

The second problem will be met by the provision of an adequate supply of cheap electric power for pumping. It may be noted in passing that the net work on one gallon of water will be about 10,000 foot-pounds, which is about one two-hundredths of one horsepower-hour. This condition is, then, one simply of cheap power for pumping, and, at a later point, we shall see how admirably this requirement may be met.

The third problem is routine in character and, so far as preliminary examination shows, presents no formidable obstacles of any character whatever. The distance from the river to the points of major consumption will be of the order of 300 miles. The provision of an abundant supply of cheap electric power for use in the construction of such an aqueduct will here likewise be an important factor in helping to render such a vast undertaking economically within reach.

It thus appears that a dam and reservoir such as that proposed at Boulder Cañon will meet the major requirement of clearing the water of silt; we shall see later as to the matter of power supply for pumping and construction purposes, and the remainder is engineering work of familiar and standardized type; and thus all conditions for a solution of the problem will be in hand once we may assume the existence of the dam and reservoir.

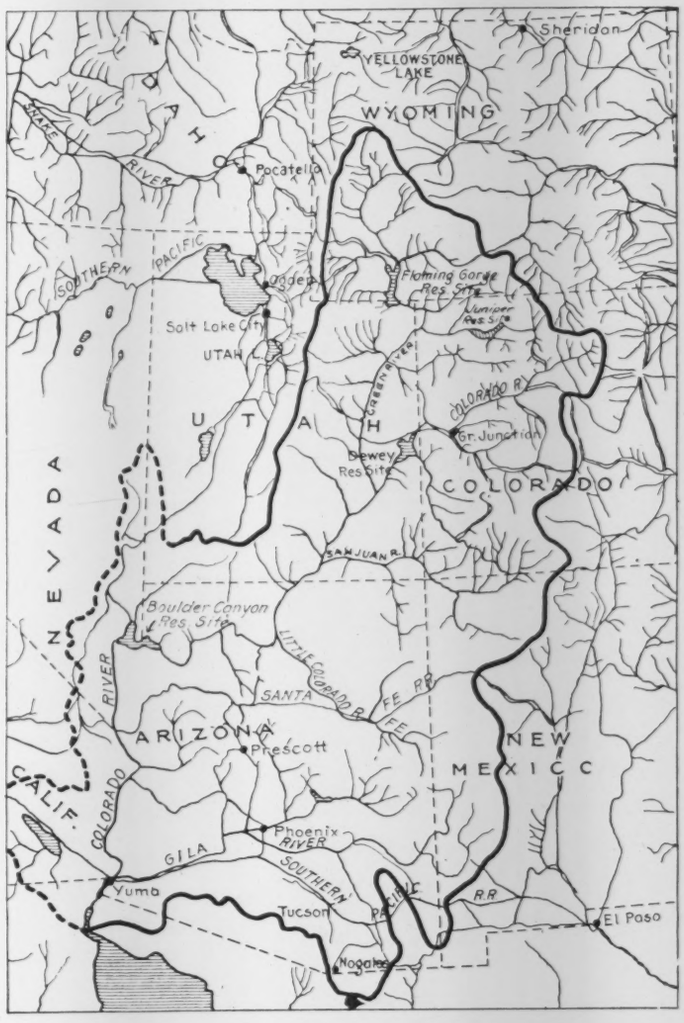
Turning next to the matter of water supply for irrigated lands, we have seen, at an earlier point, the general extent of the territory economically tributary to the river for irrigation purposes. It must be noted, however, that of this vast domain, only that part below the Boulder Cañon site, or more specifically only that part along the lower reaches of the river and especially in southwest Arizona in the Imperial Valley and in Mexico, would be susceptible of irrigation through the Boulder Cañon project. To bring in the remainder of this territory lying generally in the mountain division, other dams, reservoirs, and river-control structures must be built. The essence of water supply for irrigation is simply the storage of flood waters and of excess river flow generally, and the regulated flow of such stored waters to points of distribution for irrigation purposes. Time will serve only for the general statement that in the mountain division of the river there are a number of sites available for dams and reservoirs, and this vast area of something like 2,500,000 acres of land may be made fruitful whenever agricultural conditions may require and economic conditions may justify.

In the case of the land along the lower reaches of the river, the Boulder Cañon site is far above the point of take-off from the river for irrigation service, so that the requirement in the river below the dam is simply for a regulated flow, responsive as nearly as may be to the requirements for such service at the point or points of take-off.

In this connection there develops a very interesting problem in the comparison between the two programs of flow, both daily and annual, best suited to the development of power and to the requirements of irrigation. If these programs of flow be laid down independently, it is naturally found that while there is a considerable stratum of flow common to both programs, there are also marked divergencies, both daily and seasonal. It thus results, if the water should be released through the Boulder Cañon Dam according to the daily and seasonal program best suited to the development of power, that the requirements for the best use for irrigation could not be met; and vice versa, if the water is regulated according to the requirements for irrigation, the development of power will suffer to some extent.

As between these two partially competitive programs it has been generally accepted that the requirements for irrigation should be given the preference, and under such preferential treatment it would be found feasible, here again, to bring under cultivation this new territory as fast as agricultural conditions should require and economic conditions justify.

With special reference to the Imperial Valley, these larger developments contemplate also a new main canal from the Colorado River to the Imperial Valley and lying wholly within American territory; and such an "All-American" canal must be considered as an absolutely essential feature of any ultimate treatment of this great problem. At the present time the water for the Imperial Valley passes around through Mexican territory before entering the Valley, and this situation gives rise to embarrassments and difficulties which it is quite impossible to accept as a continuing condition. Time will permit of only the mere mention of this particular phase of the great problem of the development of the Imperial Valley, but it is one of the most fundamental and vital importance, and no solution can be considered as final which does not provide for the delivery of the water of the river to American soil without first passing through foreign territory.



COLORADO RIVER BASIN

We come finally to the fourth aspect of the general problem, the development of hydroelectric power. To this end two basic conditions only are required: viz., a supply of water and a descent from a high to a lower level, or in more technical terms, a decrease in gravitational potential. With the flow of the Colorado River brought under control and available for liberation at will from a reservoir bounded by a dam 600 feet above the present mean low-water level of the river, it is clear that the Boulder Cañon site provides all the physical conditions requisite. As a matter of fact, a detailed study of the seasonal stages of the reservoir indicates that with the amount of water at present required for irrigation from the river, and with full regard to the regimen of the river with reference to the requirements below this location, the water in the reservoir

could be kept at a level which would insure an effective head of something approaching 500 feet throughout the year. This would mean the continuous development of something like 900,000 horsepower throughout the year.

With a full development of all irrigation service economically justifiable—a condition not likely to be reached for many years—the mean flow of the river through the Cañon Division and below will presumably be reduced to something like 17,000 to 18,000 second-feet, and the mean effective head maintained will be reduced in some degree. It is anticipated that as a result of these conditions, the continuous power development at the Boulder Cañon site will be reduced to 550,000 or 600,000 horsepower.

In a plant of this magnitude and character there are many problems of detail of which lack of time prevents more than the bare mention. Such are:

1 The total installed capacity of plant
2 The character and size of the units
3 The effect on efficiency of the rather wide range in operative head which may be experienced—possibly from 550 feet to 300 feet
4 The character and disposition of penstocks
5 The character and capacity of bypass and flow-control equipment.

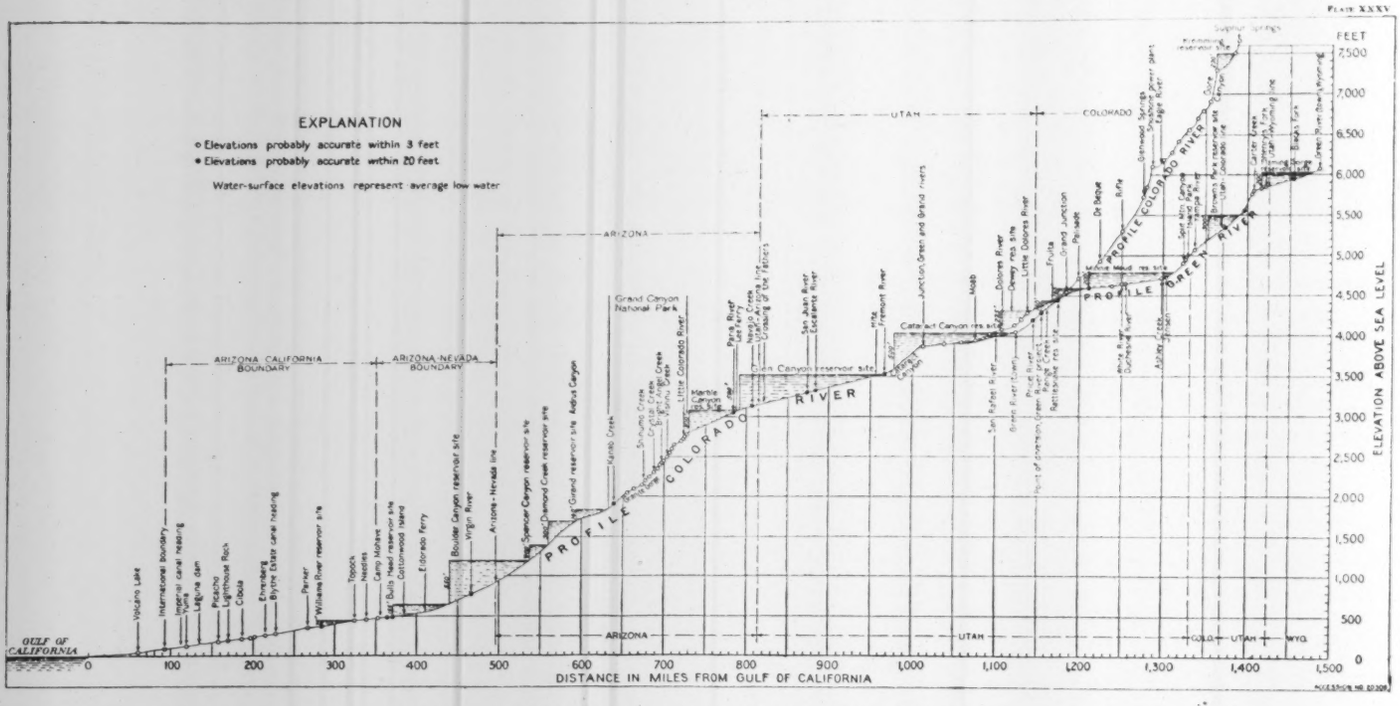
With regard to the transmission of such power to market, it is clear that, at the present time, the main market for such power is to be found in Los Angeles and general vicinity. The transmission distance is 300 miles or somewhat less, according to the ultimately selected location of a main receiving station. The conditions for satisfactory transmission over this distance at a voltage of 200,000 are now fairly well in hand, and such voltage would presumably be employed.

Regarding the costs of such power, careful preliminary estimates indicate a figure at the power house delivered to the transmission line of about one-fifth cent per kilowatt-hour. This estimate covers all operating charges, interest, and depreciation on the dam and power installations, together with a sinking fund which would retire the bonds in a period of twenty-five or thirty years. On the other hand, it assumes a market for the total output of the plant—a condition which possibly would not be realized during the first few years of operation. On this point, however, and taking into account the present rate of growth of power demand and the period of time required to complete and fully equip such a plant, it seems quite safe to anticipate a full absorption of the output of such a plant within a very short period after its completion and readiness for service.

Regarding the cost of such power to the ultimate consumer, nothing definite can of course be said, since it is well known that such cost will depend entirely on how far away he is and the extent to which the power must be subdivided and rehandled before it reaches him.

Preliminary estimates do indicate, however, that the transmission costs over a distance approaching 300 miles and for a block of such power of the magnitude of 200,000 or 300,000 kilowatts or upward would approximate 0.15 cent, making the total cost of power laid down at a main receiving station at this distance and in a block of this magnitude, something of the order of 0.35 cent.

So far, in connection with the matter of power, reference has been made only to the one site at Boulder Cañon. So far as the Colorado



Approximate Profile of Colorado and Green Rivers

River may be looked on as a potential source of hydro power, the investigations of the Reclamation Service have shown that there are a large number of sites available for such development and that, neglecting the possibilities in the Grand Cañon reservation, the aggregate power possibility in the Colorado River watershed is something of the order of five to six million horsepower, depending on the ultimate amount required for irrigation purposes.

The particular site at Boulder Cañon represents, therefore, only a small part of the ultimate possible development in this watershed—a development which must come with the increasing demand for power with the improving facilities for its transmission over long distances and with the apparently certain increase in the importance of petroleum oil for purposes other than as a direct fuel.

In conclusion it thus appears that the construction of a great dam and storage reservoir such as that indicated at Boulder Cañon would in itself provide the key which would fit into the wards of this quadruplex lock. It would insure the security of the Imperial Valley. It would be the first and most essential step toward making possible the bringing of the waters of the Colorado to the cities of southern California. It would be the first step in providing for a vast extension of fruitful land in the arid Southwest. And it would meet, for a time at least, the ever-growing demand for electric power in this section of the country. And again, what seems most definitely to put upon such a project the seal of economic approval, is the fact that the entire financing of the undertaking at Boulder Cañon can be met by the sales of power at prices distinctly lower than for power drawn from other presently available sources.

A vast national asset, capable of furnishing the solution to meet urgent present-day problems, thus awaits utilization. It will be an unpardonable economic crime to leave longer unfruitful these God-given riches.

Admiral George Wallace Melville: A Great Leader of the Engineering Profession[1]

By WALTER M. McFARLAND[2]

THE desire to perpetuate the memory of great men by some form of monument made of imperishable material must go very far back in the history of the race. We know that it certainly appears in prehistoric times. In the majority of cases these monuments have taken the form of a statue of the hero, and it is always a matter of interest, when one knows his history, to study the face and see whether the characteristics shown in actual life have been grasped and delineated by the sculptor.

When examined in this way the statue of the late Admiral Melville, which is before us for presentation to the Society, clearly shows the leading elements of his character which went to make him one of the great leaders of our profession. These elements I should list as great will power, tenacity of purpose, absolute fearlessness, and leadership. Indeed, many people who knew him in life and others who have looked at his pictures have said that he was really one of the old Vikings who had appeared a thousand years after all the rest had gone.

THE MELVILLE BUST
PRESENTED TO THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS DEC. 3, 1924

ADMIRAL MELVILLE'S FEARLESSNESS, TENACITY, AND RESOURCEFULNESS

As an example of his fearlessness and tenacity we have the case of the capture of the Confederate privateer *Florida* in 1864 in the harbor of Bahia by the United States vessel *Wachusett* where Melville was one of the junior engineers. It was, of course, a breach of international law to attack an enemy vessel in a neutral port, but the captain of the *Wachusett*, remembering the vicious work of the *Florida* in sinking helpless merchantmen, probably felt justified in risking his commission (which, as a matter of fact, he lost) by capturing her. Melville volunteered to go aboard the *Florida* to secure information, and took the risk of being arrested and executed as a spy. His visit was very brief but he did learn much of value. A council of war was held on the *Wachusett* and it was decided to attack the *Florida* by ramming. Fear was expressed by some of the officers that the shock of ramming would dislodge the boilers from their fastenings, thus breaking steam joints and scalding everybody below. Melville volunteered to stay below alone and operate the engines so that, if such an accident occurred, he would be the only one sacrificed. We know now, from the experience of many collisions, that there was no danger of such an accident, but it was not known then and he was sincere in what he believed to be a tremendous risk.

After the close of the Civil War he was almost constantly on sea duty and established a reputation for efficiency and resourcefulness which made all the older engineer officers eager to have him on their staff. In 1873 a relief expedition was undertaken to rescue a portion of the crew of the *Polaris* expedition (of which Captain Hall was the commander) and the yacht *Tigress* was chartered for this purpose. Melville volunteered as her engineer officer, and although the machinery was old and worn, his indomitable spirit and technical skill made it work, so that the *Tigress* succeeded in getting as far north as the winter quarters of Dr. Kane in a little over thirty days. The *Polaris'* survivors had gone forward and had been rescued by a whaler. Unaware of the safety of the party, and during the fierce autumnal gales of the Arctic, the *Tigress* kept up the search to the great satisfaction of the commander, Captain Greer, U. S. N., who stated officially that, despite the miserable condition of the boilers and the cheap machinery, Melville's great fertility of resource combined with thorough practical knowledge enabled them to carry on. It was on this trip that Melville and DeLong became associated, which led to their again being shipmates in the ill-fated cruise of the *Jeanette*, where DeLong perished and Melville established a record for heroism which has never been surpassed.

THE VOYAGE OF THE "JEANETTE"

The story of the voyage of the *Jeanette*, and of the retreat over the ice after the vessel was crushed and sunk, has been told in Melville's own book entitled, "In the Lena Delta" and in the "Ice Journals" of Captain DeLong. It is a story which, as a record of courage and persistence under most trying circumstances, cannot be surpassed and it has all the fascination of romance. Almost innumerable opportunities were presented for the display of his resourcefulness and technical skill in various small ways which contributed to the safety and maintenance of the vessel; and time after time Melville was called upon for special efforts entirely apart from the machinery where his wonderful qualities of leadership, persistence and courage stood out preëminently. When the group known as the DeLong Islands was discovered, Melville was given command of a party to make a landing and survey on Henrietta Island. DeLong comments upon the tremendous difficulty of this work as follows: "Near the island the ice was all alive and Melville left his boat and supplies, and carrying only a day's provisions and his instruments, at the risk of his life, went through the terrible mass, actually dragging the dogs, which from fear refused to follow their human leaders. If this persistence in landing upon this island, in spite of the superhuman difficulties he encountered is not reckoned a brave and meritorious action, it will not be from any failure on my part to make it known."

[1] Address delivered on the occasion of the presentation of the Melville bust to THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS on December 3, 1924.

[2] Mgr. Marine Dept., Babcock & Wilcox Co., New York, N. Y. Past Vice-President, A.S.M.E.

After the sinking of the *Jeanette* it became necessary to travel southward over the ice, dragging the boats on sledges, until they could come to the open sea. The crew was a small one and it was necessary for the entire party to haul the larger boats one at a time, with the result that for each mile made good there was an actual travel of about thirteen miles. The entire journey in this way amounted to some 1300 miles over this terribly broken ice. We are apt to think of traveling on the ice from our own experience with the smooth surface of ponds and rivers, but it has been graphically described as attempting to travel over the roofs of a lot of three-story houses all bunched together. Finally water was reached, they took to the boats, and the whaleboat under Melville's command was fortunate enough to enter an arm of the Lena River, where they fell in with natives and so escaped starvation. DeLong's party entered another mouth, did not fall in with natives, and all perished except the two strongest men, who had been sent forward at an earlier stage. When Melville got in touch with these survivors and learned of the possibility that the remainder of the party might be rescued he undertook a search for them. The account of this journey in the Arctic winter is a record of heroism and tenacity of purpose which has rarely been equaled. He was alone with two natives, as guides and dog drivers, with whom his communication had to be mostly by signs. The weather was so fierce that even these hardy natives were cowed and wanted to turn back. His feet were frozen and he was almost helpless, but his great will power dominated the natives and forced them to proceed until it became evident that further search at that time was useless because the party must long since have perished. The next spring he searched for them again, found the bodies, and gave them decent burial.

On his return to the states he was acclaimed a hero, but recognition by Congress was delayed a long time, and when it did come, almost ten years later, it amounted to an advance of only about ten numbers, although it was a grade in rank.

By this time Melville was one of the foremost figures in the Engineer Corps of the Navy, and the duty to which he was assigned was commensurate with his recognized professional ability and skill as an executive. When the building up of what was called the "New Navy" forty years ago began, Melville was assigned to duty as Senior Inspector at Cramp's Shipyard where a number of the vessels were under construction. At that time we were obsessed with the idea, which still lingers occasionally, that everything is better done in Europe than here at home, with the result that we bought the plans for some of our earlier vessels in England. Melville believed that he could get out designs which would be equal or superior to these and asked permission to do so. This was granted and he associated with him Chief Engineer Kafer, a contemporary, and Messrs. Mattice and Cathcart, all of them members of this Society, as well as other younger men, and together they produced the designs for the machinery which was installed in the cruiser *San Francisco*, which was one of the most successful of our early ships, as I can testify from personal service on board.

MELVILLE'S CAREER AS ENGINEER-IN-CHIEF OF THE NAVY

About this time a change was made in the office of Engineer-in-Chief. Secretary Whitney, knowing of Melville's wonderful record, recommended his appointment by the President, so that he became Engineer-in-Chief of the Navy in the summer of 1887. At this particular time the fortunes of the Engineer Corps of the Navy were at about the lowest ebb in its entire career. There were many good officers in the Corps among the older men, and for nearly fifteen years the Naval Academy had been turning out engineer graduates of whom many have made their mark in the profession. Two of them have already been Presidents of this Society, Messrs. Hollis and Cooley, and a third is about to become President in the person of Dr. Durand. What had been lacking was a virile, fearless leader. With the advent of Melville the leader had come.

His first official report as Engineer-in-Chief, written a few months after he took office, was like a cyclone compared to a zephyr in contrast with the mild effusions of his predecessors since Isherwood. It aroused a storm of criticism which went so far that certain line officers of the Navy endeavored to arouse in President Cleveland the belief that Melville was a "firebrand" and "disturber of the peace." Fortunately Cleveland was built on very much the same lines as Melville, not only as to physique but as to character. Naturally he wanted to see the report, and when he had read it, so far from finding fault or removing him, as these officers had hoped, he said that this was the kind of man he had been looking for and he only wished the Navy had more of them.

Melville was reappointed three times, so that his service as Engineer-in-Chief lasted for sixteen years, the longest career of any bureau chief in the history of the Navy Department. The whole record was one of progress, both professionally in design and construction of machinery, and in the morale and standing of the Engineer Corps. He was thoroughly progressive but prudent and careful, so that there were no breakdowns and each new ship was an additional success. Outstanding features of his work are the engines of the first battleships, of the armored cruisers *New York* and *Brooklyn*, the three-screw flyers *Columbia* and *Minneapolis*, which were the fastest large vessels in the world of their day, and the introduction of water-tube boilers.

As an illustration of the improvement in morale it may be mentioned that at the beginning of his term there was such a tremendous demand for lightness of machinery that weights were skinned down to a minimum and boiler tubes were quite thin. Within a year after the commissioning of some of the vessels there began to be trouble from corroded tubes. This was entirely unreasonable with proper attention, but an investigation showed that the cause was perfectly simple. When anything occurred to change the trim it was very much easier to run water up and down in the boilers to trim ship than to shift the boats or take other proper but less easy methods. If a scheme had been sought to ruin the boilers in the quickest time nothing simpler could have been devised than running salt water in and out of them. As soon as Melville knew this, he went to the Secretary, explained the situation, and stopped it in a very simple way. He prepared an order, which was signed by the Secretary, forbidding the use of the boilers for trimming ship and also forbidding the introduction of salt water in them except in case of emergency. If such emergency were deemed to have arisen the fact was to be entered in the engine-room log in red ink and the captain was to make a special report justifying his action in endangering the life of the boilers. This absolutely stopped the practice.

A GREAT LEADER OF THE ENGINEERING PROFESSION

The success of Melville's designs gave him international fame and he was looked upon everywhere as one of the great leaders of the profession. He had none of the spirit of secrecy which sometimes obsesses public officials and believed that, as the people of the country were paying the bills for the Navy, it was only fair that they should get such benefit from the work done as was practicable. Accordingly, in his annual reports he always included drawings showing the prominent features of the new designs, and these were undoubtedly of great value in stimulating engine builders everywhere to excellence of design and workmanship.

An event of the greatest importance in the history of the Navy was the amalgamation in 1899 of the Engineer Corps with the Line, thereby establishing beyond all question the proper status of the engineer on board ship as a fighting man. I believe that this was due in very large measure to Melville's personality, his established leadership, and the great record which he had made when the amalgamation was proposed. Another active factor was Dr. Hollis, who had been an engineer officer of the Navy for many years before going to Harvard as professor of engineering, and who had urged this procedure upon Assistant Secretary Roosevelt, afterward President. A board consisting of line and engineer officers under the chairmanship of Mr. Roosevelt was formed where Melville was the head of the engineers and I was their junior representative. It was perfectly evident from the start that Melville's personality and wonderful record were the deciding factors where differences of opinion arose. As a result of this amalgamation the fighting officer of the Navy today is primarily an engineer and the Naval Academy is a great school of engineering. To his basic training as an engineer is added appropriate work in ordnance, navigation, and seamanship to make the competent naval officer.

There was one feature of his character which perhaps does not show in his statue but which was a vital element in leadership, namely, his big heart and keen sympathy with his subordinates. No one could have asked to work for a chief who was more stimulat-

ing and at the same time considerate. All of us youngsters who had the privilege of serving under him admired him as a hero and a great engineer and we loved him as a father. He was always ready to give credit to his assistants in the most generous way. He was great enough to realize that he could give credit to his assistants without losing any himself. We were always ready to answer any call and thought nothing of working on nights and Sundays when it became necessary, counting it a pleasure to do it for the "Big Chief."

ACHIEVEMENTS FOLLOWING RETIREMENT FROM ACTIVE DUTY

He retired from active duty in the Navy in 1903, but a man of his active disposition could not be idle. He opened an office as consulting engineer and kept busy until his death. The outstanding feature of this period is his origination of the use of gearing to enable the steam turbine to be adapted economically to marine purposes. Now that it has become an established practice, it seems perhaps that it ought to have been apparent to everybody in the beginning; but the fact is that there was anything but agreement at the start that this was the best method. He aroused the interest of George Westinghouse in this idea, who furnished the money and the plant for making the early tests. During this period also he was very active in the scientific societies in Philadelphia, where he made his home. He was one of the best-known citizens, and with his long white hair and beard and handsome features was a most striking figure.

Naturally he kept up his interest in Arctic exploration and was one of the recognized authorities on this subject throughout the world. I should have said before that not long after his return from the *Jeanette* he was Chief Engineer of the *Thetis* of the Greeley Relief Expedition. On his return from that trip he was eager to go in command of an expedition to the North Pole. Unfortunately the money could not be raised to defray the expenses, so that his hopes were frustrated. It is most interesting, however, to know that he outlined in his book a plan which in essence, although modified by his greater experience, was followed by Peary in his successful discovery of the Pole. It is very pleasing to me, and I am sure was to all his friends, to notice how prompt Melville was in detecting the fraud on the part of the notorious Dr. Cook when he claimed to have discovered the Pole, although he had only gone a degree or two north of the eightieth parallel. Melville had perfectly good reasons which were convincing to me. At that time I was living in Pittsburgh and a great many of my friends believed in Cook and jeered at me for being a scoffer. They said, "You only say so because Melville says so. If he said the moon was made of green cheese you would say so, too!" This sneer was in reality a wonderful compliment to the affectionate relation which had long existed between the great Admiral and myself, which was almost like that of father and son. It is often said that no man can be a hero among his intimates, but this was not true of Melville. Those of us who were intimately associated with him and who knew him best, only grew to admire and love him more and more.

Mr. President, I realize that this very brief and wholly inadequate sketch of our great friend does him far less than justice. I can only ask you and my fellow-members to take the will for the deed, and to believe that if I were an orator I could give you an account of our departed leader which would fully satisfy your own sense of what is right and fitting.

An opportunity occurred to procure this bust[1] and it was believed that it would be a real pleasure to the many friends connected with the profession who had known him personally to join in its purchase and presentation to our Society. A committee was formed and an invitation to participate sent out with the definite statement that it was only sent to personal friends and those who would feel it a privilege to take part. Practically every one who was invited joined in the subscription, so that it represents a testimonial from about one hundred and thirty of the Admiral's friends. To me has been accorded the honor of acting as their spokesman in presenting this bust to The American Society of Mechanical Engineers, which had honored him by the Presidency of the Society and also with Honorary Membership. A more fitting place for this imperishable memorial could not be found than the rooms of our Society where it will share the honors with the statues and pictures of other great engineers. Our hope is that, as time goes on, younger men to whom his name is only a memory will be led, by looking at this superb reproduction in bronze, showing the wonderful characteristics which I have already mentioned, to study his life and from it gain an inspiration to add to the glories of the profession and to build up for themselves a great reputation.

[1] The work of Samuel Murray, a sculptor of Philadelphia, Pa.

The Preparation of Pulverized Coal

By H. G. BARNHURST,[1] FULLERTON, PA.

PULVERIZED-COAL FIRING has been so extensively adopted for boilers during the past few years that the methods of preparation of the fuel have become a matter of considerable interest to the engineering profession in general. It is the purpose of this paper to outline briefly such of these methods as have gained a field of use sufficiently wide to involve standardization of the major details in central pulverizing plants.

Three operations, crushing, drying and pulverizing, are generally required, and in addition proper means of transportation of the material are necessary. Crushing is eliminated when the coal as received is already small enough to be a satisfactory mill feed. Drying, likewise, may at times be eliminated when the moisture content of the coal as received is very low; but as this is largely a seasonal characteristic, elimination of the drying equipment is not to be recommended.

CRUSHING

The crushing operation is necessary, not only to reduce the coal to a size suitable for the pulverizers, but also to expose larger surfaces to the hot gases used for drying. Any standard type of crusher can be used, but crushers having the ability to reduce the coal to proper size in one stage, and without excessive consumption of power, are preferable. To make a satisfactory mill feed, the product of the crusher should pass a 1-in. or $1^1/_4$-in. ring to suit the present standard sizes of mills.

Coal may be stored before or after crushing. This does not affect the pulverizing, and is generally determined by the plant layout. If stored outside it is recovered by means of an overhead or locomotive crane, and then delivered to a hopper located below the tracks. A feeder, usually of the apron type, is attached to the bottom of the hopper and transfers the coal directly to the crusher, which discharges into an elevator delivering into a bin, from which it is fed to the drier.

The necessity of drying the coal before pulverizing has been often called into question, particularly by operators whose coal supply is normally of low moisture content. The facts are inescapable, however, that drying the coal considerably increases the capacity and reduces the power consumption of the pulverizers, and makes its handling after pulverizing a positive instead of a doubtful operation. Damp pulverized material is one of the most refractory substances there is to handle, hanging up and blocking at every point possible, and its transportation is unreliable and a continuous annoyance. When dried, the fuel mixes and burns more readily in the furnace, and, as the moisture must be removed either before or after entering the furnace, the effect on fuel economy is almost negligible. Even when coal is very dry as normally received, there

[1] Advisory Engineer, Fuller-Lehigh Company. Mem. A.S.M.E.

Presented at a joint meeting of the Cleveland Engineering Society and the Cleveland Sections of the American Society of Heating and Ventilating Engineers and The American Society of Mechanical Engineers, Cleveland, Ohio, Jan. 13, 1925. Contributed by the Cleveland Section of the A.S.M.E.

will be occasions when the weather will make drying essential, and the absence of proper drying equipment may cause interruptions that will prove to be far more costly than its provision would have been.

DRYING

Two types of driers are available: the rotary, which has been standard for many years, and the vertical stationary type, of comparatively recent development. The former consists of a rotating shell, slightly inclined and ribbed internally, through which the material passes by gravity in conjunction with the rotation of the drier. The hot gases are usually passed around the outside of the shell before entering and flowing through it in direct contact with the material, which is picked up by the ribs and dropped across the path of the gases. This is known as the indirect-fired type of rotary drier.

The vertical drier is a sectional box through which in the usual arrangement the coal flows by gravity on its way from the storage bin to the pulverizer. Hot gases under fan pressure or suction pass through the interstices in the body of the material and carry off the moisture. These gases are preferably taken from the boiler stack, in which case the term "waste-heat drier" is usually used. Steam-heated surfaces may also be incorporated in this drier to assist the evaporative action of the gases. The fact that this drier is stationary and occupies much less space than an equivalent rotary drier, not to mention its lower cost, makes it preferable under certain conditions.

"Cyclones" are essential for removing the dust in the discharged gases from a rotary drier, and are desirable with a vertical drier, particularly when the coal contains a considerable proportion of fines. A large volume of comparatively low-temperature gases is generally desirable, and pyrometers or thermometers are used to permit proper control. In summer there may be times when the coal will be sufficiently dry before entering the drier. In this case the coal is passed through the drier as usual, but the hot gases are eliminated.

The coal discharging from the rotary drier is received by an elevator, and the spout leading from the drier to the elevator is usually equipped with a magnetic separator for the purpose of removing any "tramp" iron that may be in the coal. Tramp iron usually consists of iron spikes, splice plates, nuts, bolts, pick points, etc. from the mining operation. Sometimes the magnetic separator is installed ahead of the crushers instead of after the drier. It is very essential to keep iron out of the pulverizers, as it increases the cost of repairs and causes delays. These magnetic separators are usually of the lifting type, although in some installations the pulley type is used.

The elevator used for delivering the dried coal to the bin above the pulverizers is of the chain-and-bucket type, and steel encased to eliminate dusting. In some cases the elevator discharges directly to the bins above the pulverizers. In other cases it discharges into a screw conveyor running in a dust-tight, sand-sealed trough, the elevator and conveyor usually being driven by the same motor.

The bins above the pulverizers should be big enough to supply the mills for two or three hours, thus permitting a steady feed and allowing some leeway in case anything happens to the drier or elevator drives.

The pulverizing is done in various types of mills, but the most satisfactory and economical results are obtained with heavy ring-type mills, in which the pulverizing elements are forced against the ring by centrifugal force. These particular mills take a feed of 1-in. or 1¼-in. material and discharge it at the required fineness. Their superiority is based upon the combination of high fineness produced, large capacities, low power consumption, and low maintenance charges.

TRANSPORTING THE PULVERIZED COAL

When the coal has been pulverized, it must be transported to the point of use. A number of methods are available, the oldest being the spiral screw conveyor, operating in dust-tight steel troughs. This type of conveyor has many defects, however, as it is hard to keep clean, is dangerous unless given proper attention, and requires considerable power, overhead runways, and often numerous motor drives, since the distance over which one flight can be operated is limited.

Another conveying system consists of a pressure-tight tank, a source of compressed air, and a pipe line leading from the bottom of the tank to the destination. In operation the tank is nearly filled with pulverized coal, sealed, and compressed air is then admitted above the coal, which forces the latter through the pipe line, discharging from the line into the furnace bins. In this system of coal Transporting the disadvantages of the screw conveyor are eliminated, but other faults are discovered, these being that more labor is required in the operation, that the coal must be accepted and discharged in batches, and that the large volume of air required makes cyclone dust collectors at the discharge end essential.

A third system, which is rapidly coming to the fore, consists of a pump having as an impeller a high-speed steel worm, which takes the pulverized coal from a hopper and forces it into a pipe line. A small amount of compressed air is admitted into the material just beyond the discharge end of the worm, and the mixture of air and coal is forced through the pipe line to the destination. The worm is specially designed to compact the material as it approaches the discharge end of the pump, and this packing effect serves to prevent the return of compressed air through the worm to the hopper. As a result the pump may be operated with an open hopper as long as an adequate supply of material is received by the hopper, which makes it ideal for transporting the coal from the mill spout to the furnace bin in one operation. The whole system is enclosed, so that there is no opportunity for dusting between the time the coal enters the mill and the time when it is delivered into the bin at the furnace.

The system is also used to take pulverized coal from a storage bin and distribute it to such points as required. A complete electrical signaling system is used to indicate to the operator when the bin to which he is pumping has been filled, and to permit him to operate diverting valves to change the flow to other bins which are in need of coal. The operation is usually made automatic, in order to avoid any chance of overflow.

This system of conveying has been used to elevate pulverized coal over a hundred feet, and to convey it distances of over a mile, the line pressure and the power required, which is comparatively low, depending upon elevation and distance. But little compressed air is required, and hence no cyclone is needed at the point of discharge from the pump line. The material as discharged is completely fluid, and levels off perfectly in the bin, retaining this condition for some time.

In addition to the advantages of dustlessness, simplicity, and adaptability, the first cost of this system is low, and likewise the charges for labor and repairs, and the repairs are easily and expeditiously made.

COST OF PREPARATION

The cost of preparation of pulverized fuel may be divided into five main items: power, labor, repairs, fuel for drying, and interest and depreciation. Of these, drier fuel might logically be eliminated, inasmuch as its effect is largely returned in increased heating effect of the coal burned under the boilers. Approximately 1 per cent of the total fuel used is required for drying, and when waste heat or steam is available the item disappears. The remaining items decrease as the capacity of the plant increases, and it is this fact which accounts for the commanding position now assumed by pulverized coal in the field of large power plants.

No set figures can be given for the ratio between these items, as they will vary irregularly with locality and with size of plant, but a maximum of 20 kw-hr. per net ton of bituminous coal may be stipulated, covering the entire process from crusher to furnace, and the charges for power, labor, and repairs may be taken roughly as in the ratio 5:3:2. These three items in a plant having a capacity of 400 tons per day, assuming power available at 1 cent per kw-hr. and labor at 50 cents per hour, would amount to 18 cents, 10 cents, and 8 cents, respectively, or a total of 36 cents per ton without financial charges. The actual preparation costs in any particular instance may be readily determined, and a large amount of published data giving complete costs under operating conditions is available.

The Development of Pulverized Coal as a Boiler Fuel

A Historical Outline Showing It not to Be a New and Untried Experiment, and that the Experience of Nearly a Century of Research May Be Applied to Present-Day Problems

By H. W. BROOKS,[1] PITTSBURGH, PA.

THE objects of this paper are, first, to reveal the fact that the combustion of pulverized fuel is not the new and untried experiment which some still believe it to be and, second, that the light of nearly a hundred years of past experience of pulverized-fuel research may be applied on our present problems in this art. In this latter connection it is rather interesting to note that the first recorded attempts at automatic fuel firing were along the lines of pulverized fuel, even before the first inventions of stokers. The fact that there are today installed in the United States nearly 12,000,000 hp. of stoker-fired boilers against a very small fraction of this amount in pulverized fuel shows that the solutions of the problems of stoker firing have been more apparent and simpler than those of pulverized-fuel firing, but the ever-increasing popularity of the latter form is best demonstrated by the growth in heating surface served by pulverized fuel during the past five years, during which time the areas served by pulverized fuel have practically doubled each year. Its effect on the stoker business is demonstrated by statistics of the Bureau of the Census, U. S. Department of Commerce, which reveal that to the date of writing this paper only during the months of October and November last did the stoker business exceed that of the corresponding months of 1923. Both stokers and pulverized fuel, however, have their proper field of usefulness and it is not probable that either will ever be standardized to the exclusion of the other. It behooves us as engineers, therefore, to survey the fields of usefulness of these two methods in order that a proper economic line of demarcation may be established so that the advantages of each method may be applied to give maximum service.

Earliest Attempts to Use Coal in Powdered Form

The first known attempts to use coal in powdered form were made in the early years of the nineteenth century, but unfortunately no records of these experiments are extant. The earliest recorded reference to work with powdered coal was that of Neipce in 1918. The first mechanical stoker is credited to William Brinton of England in 1819. The first patent on pulverized coal is British patent No. 6207, granted in 1831 to "John Samuel Dawes, Ironmaster of Bromford in the County of Stafford." This patent contemplated the introduction of fuel by means of a conical tube or feeder (into which the coal was thrown by hand) fitted to the top and extending a little beyond the mouth of each blast pipe, the feeder and blast pipe communicating with the furnace through large tuyeres. Subsequent patents were issued in 1846, 1854, and 1856 covering the art of pulverized-coal firing, but all developments thus far pertained to the manufacture of iron.

John Bourne in his Treatise on the Steam Engine (1861) was the first to advocate pulverized coal for boiler firing. He expressed the idea that the only feasible way to obtain maximum efficiencies in boiler firing was to feed the fuel and the air into the furnace premixed; to accomplish this, of course, the solid fuel had to be reduced to dust.

In the year 1868 T. B. Crampton made some complete investigations and carried out a long series of experiments in the use of pulverized coal for firing puddling furnaces and boilers. His observations and results are recorded in a paper read before the Iron and Steel Institute in 1873.

Mr. Crampton's boiler tests were conducted in a marine boiler having 1500 sq. ft. of heating surface, from which the grates were removed and the firebox lined with firebrick. The mixture of coal and air was injected into the furnace and in a 24-hour test his records show that the temperatures of the exit gases varied only from 380 to 400 deg. fahr., the evaporation being 10 to 11 lb. of water per pound of fuel consumed with a smokeless stack emission, a phenomenon hitherto unknown. This boiler performance was remarkable in the light of the knowledge then available; it satisfied all requirements save one: the operation could not be carried on continuously and thus failed to be adopted commercially. The reason for failure was lack of knowledge of proper furnace design and lack of appreciation of the relations that exist between furnace volume and rate of combustion.

About this same time—1867 and 1868—Chief Engineer B. F. Isherwood of the U. S. Navy carried out some evaporative tests at South Boston on behalf of the U. S. Government. They used the apparatus patented by Whelpley and Stoerr, of Boston, Mass. This scheme comprehended the simple operation of feeding powdered coal so as to cause it to come into contact with a supply of air for combustion. It was used merely as supplementary fuel sprayed over a bed of fuel on a grate, the idea being that the fuel entering with the column of air would meet the flames of the fire immediately upon injection into the furnace, and be quickly and completely consumed. These tests were made both with anthracite and semi-bituminous coals, the results indicating that, due to the cost of pulverization, much better results were obtained when using grates alone.

The Engineer, May 18, 1877, gives an account of an installation on a Cornish boiler in London, which was equipped with a powdered-coal system devised by S. K. Stevenson. This constituted a fire-clay retort 8 ft. long perforated with $\frac{1}{2}$-in.-diameter holes which was placed in the furnace flue. A measured mixture of coal and air was fed into the retort through a brickwork channel at the front. Comparative tests burning lump coal gave an evaporation of 6.5 lb. of water per pound of fuel burned, while pulverized-coal firing resulted in 8.3 lb. evaporation per pound of fuel with freedom from smoke. This attempt also failed due to lack of continuity of operation through slagging as well as lack of proper combustion volume and arrangement thereof.

For the greater part of the next two decades the subject of pulverized-coal firing was virtually dormant, although during this time a number of patents pertaining to the art were granted in the United States and Great Britain. These patents covered feeding and burning devices primarily; those interested in the development had not yet learned of the importance of specialized furnace design and proper fineness of pulverization, which is essential to satisfactory operation.

About the year 1895 this subject again became quite active, following the successful demonstration of Messrs. Hurry and Seaman at the Atlas Cement Company's works that pulverized fuel could be used as effectively and more economically than fuel oil for firing cement kilns. This successful use of powdered coal marked the first real advance in its industrial application and subsequently led to its adoption for metallurgical-furnace and steam-boiler firing. During the period 1895 to 1905 numerous patents were granted in the United States, England, and Germany covering a variety of devices for burning pulverized coal. Space will not permit details of these inventions, some of which, being quite ingenious, were put into practical use in isolated cases, although none of them were accepted by industry as commercially successful.

The Bettington Boiler

In August, 1906, James H. Bettington visited the United States as a consulting engineer for one of the large South African cement

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Presented at a joint meeting of the Cleveland Engineering Society and the Cleveland Sections of the American Society of Heating and Ventilating Engineers and The American Society of Mechanical Engineers, Cleveland, Ohio, Jan. 13, 1925. Contributed by the Cleveland Section of the A.S.M.E.

plants, purchasing at that time from the principal manufacturer of cement-mill pulverized-fuel equipment a plant for the Alpha Portland Cement Company. Later he decided to extend the method to boiler-furnace firing and in conjunction with Frazer & Chalmers, Ltd., of England, developed a vertically fired, bottom-burner, water-cooled boiler furnace utilizing air preheaters and unit pulverizers. Fig. 1 is a sectional view of the standard Bettington boiler, showing the path of the gases. A number of installations were made in South Africa, England, and Canada, some of which are still in operation, though in general the method of firing vertically upward did not prove feasible due to the slagging up of the feeder nozzle, difficulties of slag formation, cracking of the water-cooled burner,

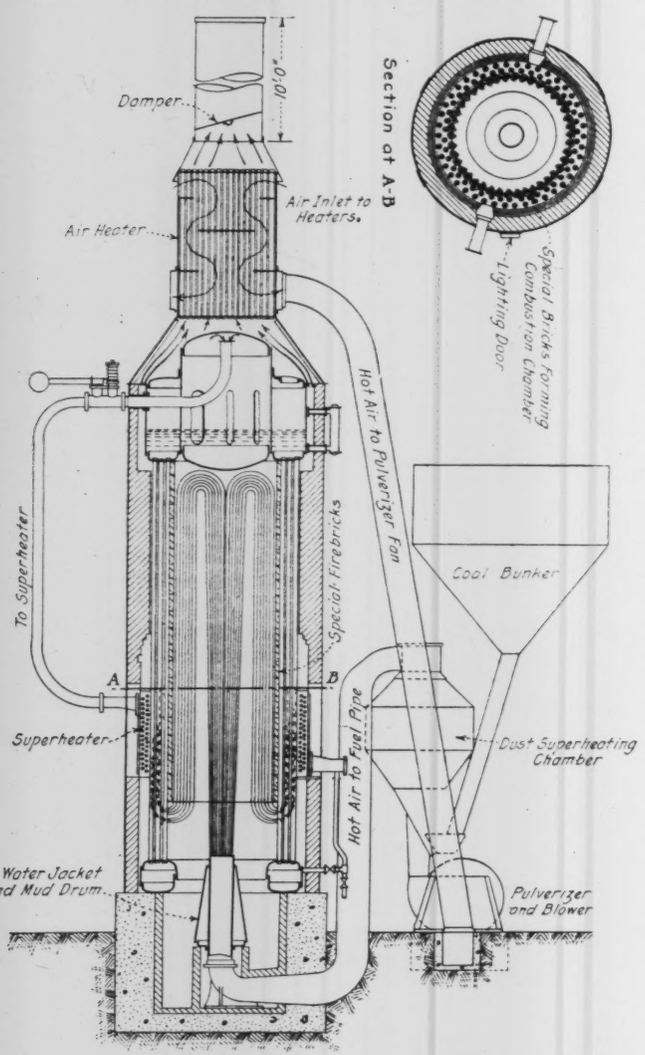

FIG. 1 SECTIONAL VIEW OF STANDARD BETTINGTON BOILER, SHOWING PATH OF GASES

and failure of the combustion-chamber lining. Bettington, however, did succeed in burning South African and Canadian coals containing 20 to 23 per cent of ash on tests at efficiencies ranging from 75 to 80 per cent, which were of a considerably higher order than had ever previously been accomplished with such fuels. He also succeeded in burning Welsh anthracite containing 13 per cent ash, though the type of pulverizer as then developed did not permit sufficient fine grinding to make the application entirely a commercial success.

PULVERIZED FUEL RARELY USED IN U. S. OUTSIDE OF CEMENT INDUSTRY PRIOR TO 1909

In the United States prior to the year 1909 pulverized coal for boiler firing was given little consideration as a commercial fuel by industrialists outside the cement industry. All the earlier investigators realized that if coal could be economically powdered and intimately mixed with the necessary air for combustion, the most efficient results would be obtained. However, they did not know or even anticipate that other factors demanded close study and that an apparently simple method of burning coal in suspension involved other considerations. The early success and apparent simplicity of burning powdered coal in cement kilns can be attributed to the knowledge cement manufacturers had of the necessity of fine grinding and their understanding of how to produce finely ground material. This was gained by years of experience in pulverizing rock and clinker for cement manufacture. Furthermore, the rotary cement kilns constituted large combustion chambers and the ash of the coal was absorbed by the clinker without deleterious effect. Subsequent experience has taught that not only must the coal be properly prepared, but the boiler furnace must be correctly proportioned to accommodate sufficient fuel to meet all steam demands. Also the form of burner used, the method of admitting fuel and air, velocity and pressure, turbulence of flow, transportation of fuel, furnace regulation, and control are problems which demand close study and experiment.

FIRST DEFINITE EFFORTS IN U. S. TO APPLY PULVERIZED-COAL FIRING TO BOILERS

It was not until about the year 1909 that any definite and substantial attempts were made in the United States to solve the various problems which had beset and defeated all previous attempts to fire boilers with pulverized coal. About this time the principal manufacturer of pulverized-fuel equipment for the cement industry conceived the idea of further developing the art for boiler firing. As this concern had been building pulverized-coal preparation equipment for the cement industry since 1895, it had already solved the problem of economical, fine, and uniform pulverization. The first attempts were to burn powdered anthracite, ground to pass a 200 mesh in a furnace at the Lehigh Foundry. The experiments showed that fairly good results were obtained when an auxiliary fire was kept burning under the jet of pulverized coal, but the furnace cooled down below the ignition point when the grate fire was allowed to go out. H. R. Barnhurst, then general manager of the Lehigh Foundry, suggested that the incoming jet of fuel be surrounded with the hot products of combustion; i.e., to construct the furnace so that the ignited gases would return toward the burner, thus preheating the incoming fuel mixture to promote and hasten ignition. A small brick furnace embodying this idea was built and operated so that the temperature could be raised to any point up to that at which the refractories started to melt. Letters patent covering this method of burning fuel were granted in June, 1910, which subsequently brought forth the statement from the late Prof. J. W. Richards that he was convinced that the basic principles of burning pulverized coal under boilers had been discovered.

Following this, an installation was made on a 72-in. by 18-ft. horizontal tubular boiler at the plant of the Lehigh Car Wheel & Axle Works. This, although an experimental installation, was operated from five to sixteen hours per day for a period of three weeks on pulverized anthracite coal. The furnace was designed so that the coal was blown in under a blind arch down around and under the incoming jet, then rising and surrounding the incoming jet with the flame, thus bringing the heat to the nozzle. These experiments were so encouraging that in 1911 an installation was made at the Allentown Portland Cement Company's plant on a 400-hp. Rust boiler. Considerable trouble was experienced due to falling out of bricks and collapsing of the arch. At first it was supposed that brick of inferior quality was to blame, but it was later discovered that a destructive condition had been created in the furnace; more coal was injected into the furnace than the available space could accommodate, resulting in high gas velocities and an erosive action which originally and erroneously had been attributed to high temperature.

This was probably the first installation in the United States in which water-cooled circulation was used to absorb heat from the refractories. Water pipes were put in the brickwork of the arch and the circulating water passed through them direct to the heater, whence it was pumped into the boiler, thus recovering the heat given up by the boiler setting. This boiler was kept in operation some time without serious trouble. Unfortunately, due to a very active market for cement which made production the paramount factor, it was taken from the experimenters and put into service

with the original stoker equipment. The cement-company officials felt that powdered coal for firing all the boilers could not be adopted at that time on account of the heavy expense and loss of output which would have been involved in changing all boilers entirely from stoker to pulverized-coal firing.

More than twenty years ago the Manhattan Elevated Railroad experimented with pulverized coal as a fuel on one of its locomotives. The equipment consisted of a combined pulverizer, blower, and steam turbine situated on a locomotive. It is believed that this experiment proved a failure on account of the lack of fineness in grinding the coal and defective methods of burning.

In 1914 the New York Central Railroad conducted tests on a locomotive of the ten-wheel type having a tractive power of 31,000 lb. It had a steam turbine direct-connected to a generator placed above the cow-catcher to generate electricity to operate the screws and secondary air blowers placed on the tender. This locomotive was successfully operated for months and ran daily between Utica and Albany, but the tests were not carried far enough by the railroad company to insure complete success.

In August, 1916, the Missouri, Kansas, and Texas Railway Company, after negotiations extending over three years, equipped eight O'Brien (Heine type) water-tube boilers at their shops at Parsons, Kansas. As a result of rising costs for fuel oil with which the boilers were originally fired, the officers of the railway company investigated other methods for generating steam. Within an economical freight-rate range of the plant were coal and lignite

TABLE 1 PERCENTAGE ANALYSES OF FUELS BURNED BY M. K. & T. R. R., PARSONS, KAN.

Kind of coal	Fixed carbon	Volatile	Ash	Moisture	B.t.u. per lb.
Mineral (Kansas)	45.22	26.39	20.38	8.01	10,640
McAlester (Okla.)	47.07	32.37	14.29	6.27	11,837
Lehigh	41.40	31.28	19.29	8.03	11,200
Lignite	25.50	33.95	7.58	32.97	7,548

mines in Kansas, Oklahoma, and Texas. These fuels differed widely in characteristics, and investigations indicated that only in pulverized form could any of them be used in the same furnace. Analyses of these fuels are given in Table 1. The sulphur separately determined ranged from 3 to 5 per cent.

A method of firing was desired by which any one or all of the above fuels could be utilized and thus divorce boiler operation from dependence on any individual fuel. Firing coal in pulverized form seemed to be the only way this result could be accomplished, and in 1913 a contract was placed for equipment necessary to supply the powdered coal and to redesign the oil-burning furnaces to accommodate the new fuel. On account of financial conditions which developed in the M. K. & T. Co., the installation was delayed until 1916. In the early part of 1916 oil prices rose abnormally and orders were given to proceed with the work. On August 1 of that year the plant was placed in successful operation and continued undisturbed until about the beginning of 1920, when the price of oil receded to an attractive figure. Since then these boilers have been fired with pulverized coal or oil alone or in combination, depending on the prevailing price of oil and the demand for steam.

It was in this plant that it was first proved that the coal must be properly dried, and finely and uniformly ground for best results; that a very definite relation exists between the size of combustion chamber and the amount of coal that can be burned in a given time; that boilers must be correctly baffled and that a scheme of baffling which is satisfactory for gas and oil firing is not necessarily the best system for pulverized-coal firing; that this method of burning fuel is not necessarily more destructive to refractories than older methods; that the disposal of ash is not a bar to its use, provided the methods are adapted to the characteristics of the coal; and that better boiler control can be obtained and better overall operating records resulted when powdered coal is used.

EXPERIMENTS ON THE FRANKLIN BOILER IN 1915

About this same time experiments were conducted on a 300-hp. Franklin boiler at the Schenectady Works of the American Locomotive Company. The first design is that shown in Fig. 2. The design of this furnace proved unsatisfactory, largely through lack of proper combustion space and was changed to the design shown in Fig. 3. The coal was introduced into the main supply of air, which was under a pressure of about 0.3 in. of water, by means of a jet of compressed air under pressure of about 20 lb. per sq. in. Charles L. Heisler, of Schenectady, in an interesting letter to the Journal of the American Society of Mechanical Engineers, written in 1916, states that the CO_2 content of the flue gases rarely falls below 16 per cent and that—

> Several evaporative tests made by W. G. Freer, member of The American Society of Mechanical Engineers, show that this extremely simple furnace illustrated in Fig. 3 gave a materially higher evaporative efficiency than could be obtained from a duplicate Franklin boiler fired by mechanical stokers and supplied with feedwater at the same temperature, and that it responded much more promptly to a sudden increased demand for steam than the adjoining stoker-fired boilers. An ordinary fire-room helper was readily taught to give the furnace all the attention ever required.
>
> Previous to the installation of this furnace, between November, 1914, and March, 1915, several constructive revisions were made in a powdered-fuel furnace experimentally installed under the same boiler. Unfortunately,

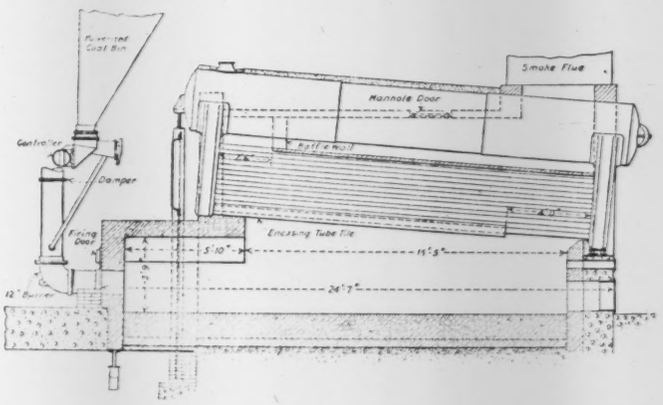

FIG. 2 300-HP. FRANKLIN BOILER AS ORIGINALLY ARRANGED FOR POWDERED-COAL FIRING

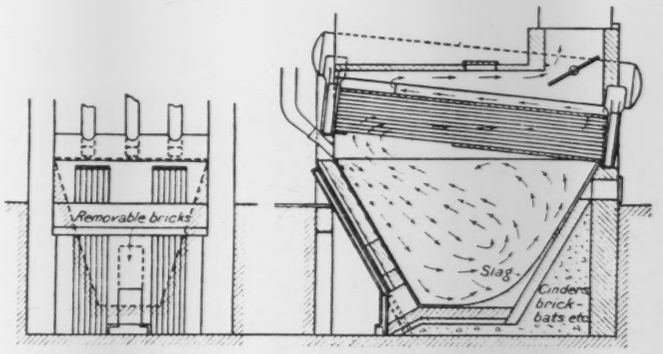

FIG. 3 FURNACE FOR FRANKLIN BOILER WHICH REPLACED THAT SHOWN IN FIG. 2

(The two sets of vertical pipes support the front wall of the furnace.)

> the brick arches and vertical walls completely failed to withstand the high-temperature flame, and there were excessive accumulations of hard slag at the bottom of the furnace and deposits of unburned products around the tubes and in the gas passes.
>
> Several years ago the writer concluded that the only way to prevent the destruction of vertical walls and arches in powdered-coal furnaces was not to have them, and to substitute incandescent ignition surfaces formed by simple outwardly inclined walls which would be automatically maintained by a coating of protecting slag. After the failure of the vertical walls and arches referred to, permission was granted by J. R. Magarvey, manager of the Schenectady works of the American Locomotive Co., to install the furnace shown in Fig. 3, which suggested itself and is shown as originally installed. This furnace now has been in continual service for 18 months without a single repair expense on the hopper-shaped furnace walls. These walls are coated with slag of a thickness of about 1 inch to 3 inches, and are seemingly in as good condition as at the time they were built. Only a small section of the old vertical wall which remained from the former furnaces was replaced at a cost of about five hours' mason's labor; otherwise, there were no repairs, with the exception of small fireclay patches under the powdered-coal inlet tuyeres, which required about 30 minutes' work.

The comparative success attained in these two installations initiated a wave of interest which resulted in numerous additional ones as shown in Table 2. The tests conducted on these plants compared more than favorably with efficiencies then attainable with stoker firing, while in some cases coals were burned which

TABLE 2 BOILER INSTALLATIONS USING PULVERIZED COAL

Date of installation	Name of company	No. of boilers	Horsepower rating and make of boilers	Furnace design, per cent of rating	Coal used
Aug. 1916	M. K. & T. R. R.	8	250 O'Brien	125–150	McAllister Cherokee slack, Kan. semi-anthracite, Texas lignites, San Bois coal, Okla.
Nov. 1916	American Locomotive Co.	1	300 Franklin	150	
June 1918	U. S. Verde Extension Mining Co.	2	439 Stirling	150	Gallup and semi-lignite
Feb. 1918	Ash Grove Lime & Cement Co.	1	371 Heine	150	Various grades of Kansas coals
June 1918	Garfield Smelting Co.	2	371 Stirling	150	Wyoming lignite, Wyopa, Wyoming lignite. Keystone, Utah, bituminous from various mines
Nov. 1918	Puget Sound Light and Power Co.	10	4—300 B. & W. 2—600 B. & W. 3—400 B. & W. 1—500 B. & W.	150	Renton buckwheat, Washington bituminous lignite and sub-bituminous
Nov. 1917	Sizer Forge Co.[1]	5	250 Rust	125	Pittsburgh and Pennsylvania
Mar. 1919	British Columbia Sugar Co.	13	2—504 Badenhausen 2—250 B. & W. 9—110 H.r.t.	150	Vancouver, B. C., bituminous and lignite
July 1918	Milwaukee Electric Railway & Lighting Co.	5	468 Edge Moor	150	Indiana and Illinois bituminous, Pittsburgh and Youghiougheny
Mar. 1919	Allegheny Steel Co.	1	333 Wickes	...	Pittsburgh coals
June 1919	Inland Steel Co.	1	250 Heine	150	Illinois bituminous
June 1918	Pacific Coast Coal Co.	10	150 H.r.t.	...	Renton buckwheat
		8	100 H.r.t.	...	Washington bituminous, lignite and sub-bituminous
Nov. 1918	Susquehanna Collieries Co.	1	250 B. & W.	200	All grades of anthracite washery culm, mine dirt, No. 3 buckwheat, Lykens slush, Lytle slush
June 1919	Lytle Coal Co.	6	333 B. & W.	200	All grades of anthracite, washery culm, Lytle slush
May 1919	Garfield Smelting Co. (2d installation)	4	371 Stirling	150	Wyoming lignite, Wyopa, Wyoming lignite, Keystone, Utah, bituminous from various mines
Sept. 1918	L. S. Smith Bldg.	2	1—300 B. & W. 1—200 B. & W.	... ...	Obtain and use coal from Pacific Coast Coal Co.
Sept. 1918	Crystal Natatorium	2	72 × 18 H.r.t.	...	Obtain and use coal from Pacific Coast Coal Co.
Sept. 1918	Crystal Natatorium	2	72 × 18 H.r.t.	...	Obtain and use coal from Pacific Coast Coal Co.
Sept. 1919	Pacific Coast Coal Co.	12	2—250 Wickes 2—125 Ames (72 × 16) 6—125 Chandler & Taylor 2—125 Casey-Hedges	...	Obtain and use coal from Pacific Coast Coal Co.

[1] Also use some waste heat from pulverized-coal-fired furnaces.

TABLE 3 DATA OF EARLY TESTS MADE ON PULVERIZED-FUEL PLANTS

Date of test	Location of plant	Duration hr.	Coal used	Efficiency maintained, per cent	B.t.u. per lb. of coal as fired	Ash, per cent	Rating, per cent
Apr. 16, 1917	Seattle, Wash.	14.5	Renton buckwheat	77	10,000	11.60	122
Dec. 4, 1917	Chanute, Kan.	5	Kansas bituminous	72	11,996	17.7	125
Dec. 12, 1917	Chanute, Kan.	5	Kansas bituminous	83.94	12,500	18.25	125
Jan. 28, 1918	Chanute, Kan.	(25 days)	Kansas bituminous	78.1	11,435	...	100
Apr. 26, 1918	Parsons, Kan.	6	Kansas bituminous	80.3	12,900	17.49	...
Apr. 28, 1918	Parsons, Kan.	6	Kansas bituminous	80.9	12,289	17.49	130.8
June 14, 1918	Milwaukee, Wis.	12	Illinois and Indiana screenings	83.3	10,897	15.89	117.7
Nov. 5, 1918	Lykens, Pa.	10	Lykens No. 3 buckwheat anthracite	84.2	12,530	16.92	135
Nov. 15, 1918	Lykens, Pa.	5	Lykens slush buckwheat anthracite	81.2	13,653	11.09	142
Nov. 22, 1918	Lykens, Pa.	5	Lykens slush buckwheat anthracite	85	12,753	18.04	146
Nov. 23, 1918	Lykens, Pa.	5	No. 3 buckwheat anthracite	72.7	12,530	16.91	115
Dec. 2, 1918	Lykens, Pa.	5	Lytle slush anthracite	75.3	15,420	23.92	188
Feb. 1, 1919	Seattle, Wash.	24	Issaquah screenings	78.95	11,660	14.31	126
Feb. 2, 1919	Lykens, Pa.	4	No. 3 buckwheat anthracite	78.9	13,067	14.02	177
Apr. 7, 1919	Vancouver, B. C.	4	Nanaimo slack	83.3	9,364	28.4	125
Apr. 17, 1919	Vancouver, B. C.	5	Nanaimo slack	77.1	10,050	24.3	160
Feb. 3, 1919	Lykens, Pa.	5.5	No. 3 buckwheat anthracite	78.9	12,530	14.00	...
Sept. 24, 1919	Verde, Ariz.	(6 days)	Gallup, New Mex.	79.5	10,680	14.31	155

previously had never been successfully handled on stokers. Table 3 gives particulars rearding these early tests.

The pioneer large central-station installation was made in 1920 when the Milwaukee Electric Railway & Light Company installed eight new 1306-hp. Edge Moor boilers in the Lakeside station to use powdered coal exclusively. This plant was decided upon after the company had experimented for a number of years with powdered coal in its Oneida Street plant, by which they were convinced that this method was the most satisfactory, efficient, and economical. The new plant was designed and built under the direction of John Anderson, Chief Engineer, in collaboration with the engineers of the two largest pulverized-fuel-equipment manufacturers, one of whom furnished the driers, pulverizers, and conveying equipment, while the other furnished the feeders and burners which deliver the fuel into the furnaces. Under operation they have developed 200 to 300 per cent of nominal rating continuously. Here all of the best experience of the past was applied and the irrelevant and erroneous eliminated to the extent that when tests were made in 1921 by the U. S. Bureau of Mines in coöperation with the designing and operating engineers, the claims for the new method of firing fuel proved more than justified.

This installation has given such remarkable results that the plant is being doubled in size in order to relieve the older stoker-operated plants.

Pulverized-coal firing may be considered to have passed the experimental stage for industrial use in 1916 and for central-station use in 1920. Not only is this system of firing entirely relied upon in some large and important plants, but it has been adopted in connection with some of the largest steam-boiler units yet installed. The principle of pulverized-coal firing permits of large furnace capacities and the tendency is now toward much larger boiler units and a very much higher operating rating than has hitherto been thought possible.

Large Boiler Installations Now Using Pulverized Coal

Impressed by the possibilities of pulverized-coal firing, many of the large boiler installations made during the past four years have adopted this method, the present year witnessing some 1,060,000 to 1,100,000 sq. ft. of new installations served. There are now at least 300 installations in this country in which pulverized coal is used and nearly twenty million tons of coal per year are being pulverized and burned. Table 4 gives a list of the more prominent installations and contracted installations.

This list of installations serves to indicate the great diversity of boiler types, sizes, and ratings which are fired by pulverized coal. In each case one of the primary if not the fundamental reasons for using pulverized-coal firing is the great economy and efficiency which results. However, there are some instances among those noted above in which efficiency and economy of operation was not the dominant idea but they resorted to the use of pulverized coal because they believed that in the powdered form those fuels which were available at a nominal cost could be used to better advantage.

Conclusion

The foregoing necessarily brief historical review shows that the main principle of introducing the fuel and air together was conceived nearly a century ago, but was not put into successful operation till comparatively recently. It will be granted by all that it is at least a valuable additional method that will bring great benefits to mankind, and will help in conserving our fuel supply. In view of this it is of interest to us as the present-day representatives of the engineers of the past 100 years, to ask ourselves as to whether the long delay in beginning to reap benefits from the idea indicates failure in knowledge, ability, or energy on the part of the profession. The requisites of the necessary details now appear very obvious, and are based on elementary principles consequent on the main principle or on each other. It is granted that its present preëminence is due to its more peculiar adaptability to superstations, for which there was no necessity until recently; but if, on the other hand, development had proceeded more rapidly it cannot be believed but that its application to smaller installations would have grown, thereby affecting its own economy as well as setting the pace for alternative methods.

Without wishing to make too sweeping a statement, it would

TABLE 4 LIST OF PROMINENT PULVERIZED-COAL INSTALLATIONS IN OPERATION OR CONTRACTED FOR

Company	Number of boilers	Make	Hp. each	Total hp. installed	Per cent rating
Lima Locomotive Works	6	Wickes	400	3400	150
	1	Heine	500		
	1	Wickes	500		
Lytle Coal Co	6	B. & W.	333	1998	200
Broadway High School	3	H.r.t.	125	375	125
New Richmond Hotel	1	Scotch M Dry back	100	100	125
Southern Anthracite Mining Co	1	B. & W.	250	250	200
Cayuga Operating Co	4	Heine	300	300	150
Bethlehem Steel Co	4	B. & W.	520	2080	175
Standard Furniture Co	2	B. & W.	150	300	125
Morris & Co	5	Edge Moor	500	3100	200
	2	Edge Moor	300		
Falcon Steel Co	2	Badenhausen	200	400	
Susquehanna Collieries Co	6	Edge Moor	600	6600	200
	6	Edge Moor	500		
St. Joseph Lead Co	4	Stirling	768	1532	200
Ford Motor Co	4	Ladd	2640	10,560	250
Illinois Malleable Co	2	Wickes	300	600	150
W. B. Eline Co	4	Wickes	500	2000	200
American Chain Co	1	B. & W.	300	300	150
Milwaukee Electric Railway & Light Co	8	Edge Moor	1306	10,448	200
Cayuga Operating Co	3	Keeler	300	900	150
Duquesne Light Co	1	Stirling	823	823	300
Trumbull Steel Co	2	Stirling	400	1400	200
	1	Stirling	500		
Tennessee Coal, Iron & Railway Co	6	Stirling	823	4115	200
Norfolk & Western Railway Co	6	B. & W.	200	3200	175
	5	B. & W.	400		
U. S. Coal & Coke Co	2	B. & W.	789	1578	200
Ashtabula Steel Co	2	Union	444	888	150
Pennsylvania Salt Co	1	B. & W.	822	822	300
Kobe Municipality	1	B. & W.	555	555	
Western Light & Power	1	Stirling	550	550	
Ford Motor Co	4	Ladd	2647	10,588	250
Ford Motor Co., Canada	3	McAleenan	1350	4050	300
Firestone Tire & Rubber Co	3	Stirling	600	1800	200
Toho Electric Co	1	B. & W.	800	800	
Walker Soap Co	1	Stirling	450	450	
Mathieson Alkali Co	2	Wickes	500	3825	150
	4	Wickes	250		
	3	Wickes	275		
	4	Cahall	250		
St. Paul Gas Light Co	3	Heine	1000	3000	300
Farr Alpaca Co	3	Crossflow	1000	3000	300
Clark Thread Co	10	Stirling	500	5000	200
Cleveland Elec. Illum. Co., Lake Shore Plant	4	Stirling	3060	12,240	225
Rochester Gas & Electric Co	4	B. & H.	875	3500	200
Union Electric Light & Power Co	8	B. & W.	1780	14,240	250
United Electric Railway	3	B. & H.	1266	3798	200
West Penn Power Co	1	B. & W.	1800	1800	200
Falcon Steel Co	1	Badenhausen	500	500	
Otis Steel Co	2	Stirling	834	1668	200
United Electric Light & Power Co	6	Springfield	700	4200	275 to 400
Binghamton Light, Heat & Power Co	1	Edge Moor	1200	1200	200 to 300
Metropolitan Power Co		Connelly			
Sloss Sheffield Steel & Iron Co	2	Stirling	600	1200	250
Detroit Edison Co	6	Stirling	3000	18,000	250 to 300
Ougree Marihaye, Liege, Belgium	1	Eslingen	210	210	
	1	B. & W.	150	150	
	2	Bailey-Mathot	190	380	
	2	B. & W.	180	360	
	3	Garbe	278	834	
Mines de Blancy, France	1	B. & W.	205	205	
Beautor, France	4	B. & W.	278	1112	
Union Minière Du Haut Katanga, Belgian Congo	6	Stirling	300	1800	
Columbia Power Co	8	B. & W.	1500	12,000	225 to 300
Allegheny County Steam Heating Co	1		3275	3275	
Illinois Electric Power Co	4		1392	5568	350
City of Winnipeg, Canada	3	Erie City	110	330	250
Pennsylvania Cement Co	1	Edge Moor	505	505	250
El Charquito Power House, Bogota, Colombia	2	Springfield	323	646	
Ford Motor Co	2	McAleenan	1350	2700	250
Sioux City Gas & Elec. Co	3	Stirling	1112	3336	250
Cleveland Electric Illuminating Co	3	Stirling	1500	4500	300
Narragansett Electric Lighting Co	2	B. & W.	1708	3416	350
	2	B. & W.	1875	3750	320
St. Joseph Lead Co	2	Heine	1000	2000	300
Allegheny Steel Co	2	Stirling	779	1558	200
Penn. Water & Power Co	3	B. & W.	1405	4215	300
Pejepscot Paper Co	1	Stirling	600	600	200
Trumbull Steel Co	5	Stirling	500	3900	200
Tennessee Coal, Iron & Railway Co	2	Stirling	823	5761	200
Pennsylvania Water & Power Co	3	B. & W.	1405	4215	200 to 250
Ford Motor Co	2	Ladd	1361	2722	200
Ford Motor Co	2	Springfield	500	1000	200
American Spiral Pipe Works	1	Bigelow-Hornsby	760	760	150 to 200
Middletown Car Co	2	B. & W.	250	500	150
Peerless P. C. Co	1	Ladd	500	500	200
U. S. Metals Ref. Co	2	B. & W.	400		
	2	Stirling	779	2358	250
Ball Brothers Co	2	Stirling	300	600	150
Southwestern P. C. Co	1	B. & W.	1000	1000	
Weirton Steel Co	3	Stirling	602	1806	200
New Orleans Public Service Co	1	B. & W.	2000	2000	200 to 300
Metropolitan Power Co	5	Connelly	1500	7500	250
Queensboro Gas & Electric Co	2	B. & W.	600	1200	200
Fordson Coal Co	3	B. & W.	600	1800	200

seem to the author that there was an apparent cessation in the rate of development of this and other engineering arts lying roughly between the years of 1840 and 1900, due primarily to engineering education not having kept pace with the advance in the quality and quantity of work accomplished, and partly to a lack of appreciation of the limitations to the then apparent natural resources.

The question for ourselves, as engineers, is whether there may be other primary principles that we are overlooking or do not foresee.

Present and Future Power Equipment

IN THE December, 1924, issue of *Management and Administration*, Hubert E. Collins, writing on Present and Future Power Equipment, says:

"Visions of new sources of power have been numerous during the last three decades. Many of the new suggestions seemed good from the viewpoint of adaptability and economy, so much so at first, that the newcomer was expected to supplant many old-timers. As time has flown, and the old-timers have held their ground, and results have been checked up, we find that the new and the old each has its own field where it can make good. It is not alone a case of deciding which type of prime-mover is the best for general application, but which is best for individual power-plant needs. First cost, operating cost, and all items entering into the cost of a delivered horsepower while supplying *all* the needs of the plant, make the decision of the proper prime-movers an almost individual study.

"In an analysis recently made by *Electrical World* it is shown that with waterpower development proceeding as rapidly as possible, the steam electric station will still be the most important single factor in the supply of central-station service and in the industrial-company field as well. Gone, then, is the vision of "white coal" being supreme, with the steam prime-mover manufacturer out of business."

Mr. Collins reaches the following general conclusions:

"At the present time all classes of prime-movers discussed with whatever auxiliaries each requires for commercial hp. production are near even in production cost. Some are better than others under special conditions, but if each installation were exactly fitted to the total requirements of the individual plants, the power production costs would be found on an almost flat curve.

"Present rates may be reduced somewhat, but the greatest benefit lies in checking the tendency to rise, and the preservation of a normal rate for some time to come. The question will arise in the mind of the reader as to whether he should purchase power of the central station or generate in his own plant, and if the latter, what class of prime-mover will he use? Dividing the industries into three classes we answer the question as follows:

1 Industries using power, with steam only required for heat, will purchase power from the central station and generate steam only for heat. In isolated sections, the industry may find their own plant of oil-electric prime-movers the best solution

2 Industrial plants requiring power, and steam for process and heat, in general will generate their own power by steam-electric prime-movers, or, in isolated sections, by means of oil-electric prime-movers

3 Plants whose processes give a large amount of by-product or waste available as a fuel, should generate their own power as the basic cost of it is in fuel.

"In other words this whole discussion discloses the fact that the central stations and private-owned plants each have an open field, with all classes of prime-movers finding a field of service, because rates are now so near equal.

"If the purchase of power from the central station looks inviting to the private plant owner, he should have a competent engineer to go over load conditions that are to be met in order that the most advantageous rates obtainable will be supplied. Where a private plant for all needs seems best, the engineer should first study conditions. By "engineer" is meant one in the regular employ of the company or an outside consultant, but always one who is not a sales engineer for any engineering device."

Education and Training for the Industries

Industry's Interest in Increasing the Number of Those Receiving Apprenticeship Training—A Coöperative System for the Training of Metal-Trades Apprentices—Principles Involved in Vocational Training and How Such Training May be Achieved

ONE of the best-attended sessions of the A.S.M.E. Annual Meeting in December dealt with the subject of non-college-type industrial training. At this session, held under the auspices of the Society's Committee on Education and Training for the Industries and presided over by its chairman, Prof. John T. Faig, George B. Thomas, Educational Director of the Western Electric Company, summarized the industrial educational work of the American Management Association and its predecessors, the National Association of Corporation Training and the Industrial Relations Association of America; and papers dealing with various phases of the apprentice-training problem were presented by Magnus W. Alexander, Frank Cushman, and H. A. Frommelt. These three papers, slightly abridged, and extracts from the discussion that followed are given below.

Industry's Interest in Industrial Training

By MAGNUS W. ALEXANDER,[1] NEW YORK, N. Y.

I WISH to congratulate The American Society of Mechanical Engineers upon having reserved a session at this Annual Meeting for a discussion of Education and Training for the Industries. On an occasion like this all time is precious, and therefore to have set aside the time for this meeting is an indication that the Society recognizes the importance not only of efficient education for engineers but also of efficient training for artisans for the industries, both of whom are essential to industrial conduct and development.

Statistics of Employment

Confining this discussion essentially to industry's interest in industrial training, it should at once be realized that this interest affects a very large part of our population since our present civilization is essentially industrial in character. According to the United States Bureau of the Census, of the total population of 105,710,620 in the United States in 1920, there were 41,614,000 or 39.4 per cent engaged in gainful occupations, such as manufacturing, mining, agriculture, transportation, wholesale and retail trade, public, professional, and clerical service, and domestic service. It goes without saying that for all of these activities some kind of training is necessary, no matter how low the grade of service. Even the common or unskilled worker is in need of some training, for, while he uses his body mainly, he must know how to apply that brawn to his labor in order to accomplish a given result. The lower the degree of his training and the lower the degree of intelligence applied by him, the less will be the effectiveness of his work and the less, correspondingly, his remuneration and reward. Any one familiar with the interesting experiments carried on by the late Frederick W. Taylor at the Midvale Steel Company knows what training of common labor under the direction of intelligent management can accomplish. This phase is too well known a chapter in scientific management to need any elaboration.

But it is not alone these more than 41,000,000 gainfully employed persons that require training. In the group of persons ten years of age and over are another 41,000,000 persons, comprising mainly married and unmarried women either engaged in unpaid household duties or remaining at home without doing any special service, also persons incapable of work because incapacitated by accident, illness or old age, and a small number of idlers. A. M. Edwards, of the United States Bureau of the Census and an authority on occupation statistics, estimated that in 1910 there were 18,000,000 American women sixteen years of age and over engaged in housework in their own homes without monetary remuneration. If that proportion of housewives to total population remained constant, their number in 1920 would have been about 20,700,000. By adding this number to the 41,600,000 engaged in gainful occupations, it is seen that there are approximately 62,000,000 persons in this country for whom some kind of training is necessary if they are to be of adequate service in our economic society. This outline is here presented in order to focus attention on the magnitude of the problem of training for economic service to society and to emphasize the importance of its proper consideration.

In considering industry's interest in industrial training, I use "industry" in the sense of the manufacturing and mechanical trades. Here a new set of interesting and suggestive figures presents itself. In 1920 there were 12,818,524 persons engaged in manufacturing and mechanical industries; but this does not include professional service with its more than 600,000 administrators, supervisors, and technical experts, of whom the National Industrial Conference Board estimated that about 150,000 were engineers and technical specialists in industry. A redistribution of this group of 12,818,524 persons gainfully occupied in manufacturing and the mechanical trades, in high or low positions, into classes of persons with various degrees of skill, is interesting and pertinent to this discussion. It shows that of the total, 4.1 per cent or 523,445 can be classified as persons in major technical and supervisory positions, with the remainder divided among 2.4 per cent or 307,413 foremen and overseers, 41.1 per cent or 5,266,918 artisans with various degrees of skill, 28.4 per cent or 3,635,960 semi-skilled operatives, and 22.9 per cent or 2,940,611 unskilled workers, as well as 144,177 apprentices in training who constitute but slightly over 1 per cent of the total. Obviously, if those in managerial and supervisory positions are to carry on their tasks successfully, they must have behind them a body of trained personnel, sustained in numbers so as to offset depletion from whatever cause and capable of rapid augmentation to meet increasing quantitative and qualitative requirements of an expanding industry. Behind these groups of commissioned and non-commissioned officers, a great army of lesser trained and untrained workers under effective leadership can be led to high industrial achievement.

Need for Vocational Training

The number of persons to be recruited to industry in each occupational class depends upon the rate of growth of industry and the loss from death and promotion and by permanent retirement. Investigations covering the period from 1900 to 1920 indicate that the number of persons engaged in industry is increasing at the rate of about 35 per thousand per year. The annual death rate, as revealed by the vital statistics of the United States, is approximately 10 per thousand, while the number of persons permanently leaving industrial occupation, whether by promotion, retirement, or transfer to other occupations, may conservatively be estimated at 5 per thousand per year in excess of those transferring into industry. The total number of persons that must annually be recruited to industry to sustain its present rate of growth may therefore be set at 50 per thousand, or about 5 per cent of the total number employed. This figure is a conservative estimate since it does not take into account the effect of our new immigration restriction in the face of an improving European economy. The bulk of the immigration under the recent per centum limit immigration acts has been largely female. The principal need of industry is largely for male help. The decreased supply of immigrant labor will involve a larger proportion of skilled workmen in order that the production per man may be increased and thus offset the advantage of foreign competitors in their abundant supply of cheap labor. If it is now assumed that the ratio of 5 per cent applies equally to the skilled occupations in industry as well as to industry as a whole, a measure of the number of annually needed recruits who require organized industrial training is at hand. This training may be supplied in a varying degree of completeness by

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a Apprenticeship courses
b Manual-training, vocational, and trade schools (including evening industrial and continuation schools)
c University and state extension courses, and
d Upgrading processes within industry.

The latter method, through which those on lower industrial levels rise to higher levels of skill and usefulness, is the most natural process, but left unaided in its natural development it tends to be at best a haphazard process designed to meet some special needs and totally inadequate to serve the bigger purposes of industrial advancement. On the other hand, where such methods have been regularly and intelligently organized and guided, this upgrading process has yielded rich results at relatively small cost, and more along these lines may yet be done for the equal benefit of industry and its mass personnel. In general, however, upgrading even in organized form will ultimately fill the industries with productive men of only limited usefulness and capacity and leave still unanswered the great call for skilled artisans with industrial intelligence and potential capabilities to meet extraordinary conditions and to supervise groups of workers and plan their work.

This need must be filled through the other methods outlined, but it can be said without hesitation that a well-organized and efficiently conducted apprenticeship system in industry is the most thorough and complete method of producing skilled workmen. On the other hand, the chief value of educational systems outside of industry lies in providing a pre-apprenticeship training as a broad vocational basis on which subsequent training in industry can proceed with greater ease and effectiveness. Thus reducing the necessary period of apprenticeship in industry, this basic vocational education exerts its value in the direction of developing certain habits and attitudes toward practical work and tends to eliminate those not suited or inclined for industrial activity. The industrial work itself, however, can best be taught and performed in an atmosphere of practical work life and when conditioned by the daily incentives and taskmasters of time and money. No discipline stands by us so well as that obtained by life's experience. No amount of object lessons given primarily for the sake of imparting information and training the mind can supplant, although it can materially supplement, the great value that arises from personal contact with the activities of life and from actual participation in these. This is what the apprenticeship system does; it presents the real problems of the work day in the way the workman finds them. It is the training system that, if properly carried on, is best suited for the needs of industry since it is a part of industry. A happy combination of vocational or pre-apprenticeship courses through regular educational agencies and of well and properly organized apprenticeship training in industry, with the connecting link of close coöperation between the human forces back of these two methods, bids fair to serve best alike industry, its workers and society.

Decrease in Apprenticeship Training

Those familiar with industrial production know, and various investigations have shown, that there is now and has been for some time a decided shortage of provision for the practical industrial training of those whom industry requires as skilled artisans. Apprenticeship training has decreased in the last decade while the need for it was growing. The explanation may be that because of the enormous expansion of industry during and immediately following the World War, especially in respect to mass production, the demand for workers was abnormally greater, and therefore such high wage earnings were offered to even those with little or no special skill that the resultant trend was away from, instead of toward, systematized apprenticeship training in which "to learn" takes precedence over "to earn." It is important to note also that economic organization has grown increasingly complex so that each individual has become more or less a specialist familiar only with those processes and sets of facts which are involved in his specialty, but with little or no knowledge of broader character.

A century ago, when the economic organization of society was simple, the average individual was required to perform in the household and in connection with the household a wide variety of tasks, and thus was obliged to come intimately in contact with the problems and realities of life. This contact provided a definite vocational background. Such articles of clothing, utensils, and mechanical appliances as were needed in the household were largely made by those composing the household; and the needed food was raised in close proximity to the home. The management of the household imposed work upon all in it and thus contributed in large measure to the vocational training that was required for that period. Today this condition no longer applies. Instead of sharing in a rounded life we share only in a part, with the result that our experience is not only considerably limited but the former training for all-round usefulness has largely ceased. Similarly, the small workshop of a few decades ago with its small number of all-round artisans offered a fine opportunity for developing a keen taste for industrial work, and also favorable conditions under which to learn that work. The modern factory and mill with its multitude of workers and its high specialization of work does not offer the same incentive and even seems to cast doubt on the need for old-time, all-round skilled industrial artisans. Yet, such an assumption does not rest on facts; the truth is that there is today even greater need and opportunity for all-round skilled artisans to design, construct, install, and operate, and to teach others to operate, the complicated machines and mechanisms which high specialization and intensity in industrial production necessitate. The old idea of apprenticeship training, brought to a high state of development during the period of the trade guilds, needs restatement and reincarnation in a new form to suit the conditions and circumstances of modern economic life.

Number of Apprentices Needed

As stated before, the necessary annual recruitment in the ranks of skilled artisans in the manufacturing and mechanical industries seems to be about 5 per cent of all such artisans employed, but this would not provide for any material expansion of industry except in so far as this may be brought about by a greater utilization of machines and power. What number, then, should be undergoing industrial training through apprenticeships or adequate educational substitutes? On the basis that apprenticeship courses vary in length from three to four years, according to the different occupations for which they train, in order that the needed 5 per cent may be available for industry each year, from 15 to 20 per cent of the total number of skilled workmen employed should be enrolled in such training courses, assuming that only where skill is required in the regular work such training should be provided. The total number of artisans with various degrees of skill is, as already stated, 5,266,918. Since, no doubt, there are included in this figure many who may have reported themselves as skilled workers whereas they might only possess a very limited amount of skill, it would be only fair for purposes of this discussion to eliminate these and thereby reduce the total number of those requiring special training for efficient craftsmanship. A total of 4,500,000 would, on this basis, be a conservative estimate. In other words, instead of 144,177 apprentices that were in training in industry in 1920 according to the United States Census, there should have been from 675,000 to 900,000 apprentices indentured in apprenticeship courses, if these alone were to fill the requirements of industry for skilled artisans and for foremen and supervisors. This does not take into account, however, the natural loss of any sort, such as from voluntary or involuntary termination of the training before its completion. It may not be necessary, of course, or even desirable that all skilled artisans be developed through apprenticeship courses, but a large part, no doubt, should have such systematic, well-grounded preparation if the demand for competent skilled workers and foremen in industry is adequately to be met.

In this connection it is interesting to reflect that the apprenticeship system is recognized by many labor unions as a means of proper preparation for craftsmanship, and, although many of these unions have set maximum limits to the permissible number of apprenticeships lest too many enter the trade, this ratio generally runs from one apprentice to every five journeymen to one apprentice to every ten journeymen.

With these figures in mind, on which the previous estimate of from 675,000 to 900,000 apprentices that should have been in industry in 1920 is predicated, and on the basis of about 142,000 pupils enrolled in trade or industrial schools, not including part-time general continuation schools, according to the report for 1923 by the

Federal Board for Vocational Education, it may be generally stated that industry is neglecting its obligation for training its future supply of skilled workers to the extent of at least 390,000 apprentices, of whom an average of from 97,500 to 130,000 graduates would be annually available for craftsmanship in industry.

RESPONSIBILITIES OF INDUSTRY AND OF SOCIETY

Surely, here is a challenge to industrial management to do not only that which is for its own best, but at the same time to do that which would help elevate the industrial capacity of the country and, therefore, help to increase its prestige throughout the world and its wealth-producing power at home. Naturally, more attention would have to be paid and more money would have to be expended in industry by industry for the accomplishment of this purpose, but it should be easily demonstrable that such expenditure would be an excellent investment.

But the challenge does not lie only against industrial management; it lies equally against society, which, through its educational agencies, should make adequate provision that in our time and day of preëminently economic organization sufficient attention and emphasis is given and sufficient expenditures are made for vocational preparatory education without neglect of the fundamental cultural training for general intelligence and knowledge and for development of good citizenship.

Industry's interest in the right answer to these challenges is paramount. While industrial leaders must take an active interest in securing provision for an adequate amount of industrial training in and outside of industry, the interest in this subject transcends the boundaries of industry and reaches directly into the community. Industry and industrial training are matters of vital importance to the community because the character of our national life is largely industrial. To the extent to which the members of the community are concerned in its economic welfare, they must share with industry a vital interest in industrial training, even though the burden for securing it must rest heavily upon those responsible for industrial production. Moreover a broader attitude must be taken by industrial management toward this question. In times not far remote education for culture only seemed to have the complete approval of the public while industry seemed to care only for practical training. Now it is becoming more and more apparent that the latter is, after all, only a phase of the former. By so balancing the educational system that fundamental cultural education will have adequate expression in applied training for usefulness, industry and the public will alike benefit; and industry, because this matter strikes right at the heart of its operation, must take the initiative. Above all the responsibility and duty rest upon industrial management to organize its own broad and efficient program of apprenticeship training within its own jurisdiction, both to supply its necessary skilled man power and by this practical example guide the community in its program vocational education. This is Industry's Interest in Industrial Training.

The Need for District Organization of Modern Apprenticeship

BY H. A. FROMMELT,[1] MILWAUKEE, WIS.

AMERICAN industrial apprenticeship has usually been organized within the confines of individual plants. It is significant to note that, while some individual plants have become known for their well-developed training programs, apprenticeship has not become a general feature of modern American industry. The result is a lack of skilled workmen, from which industry as a whole is suffering. Is it not reasonable that apprenticeship, if it is to be satisfactory in modern industrial life, must not be confined to individual plants? In our efforts to develop a program in the individual plant, may we not have overlooked the advantages of training programs based on a coöperative group of plants?

Great changes have taken place in modern industry since the eighties and nineties of the last century. In those days apprenticeship was more possible for the individual plant. Organizations then were little given to specialized products and operations. The manufacturing plant, whatever its product, carried through to completion all essential operations. Today there are few such organizations. Division of labor, and specialization generally, have brought about a breaking up of these complete units in the manufacturing world. Few trades, especially in the metal industries, are completely represented in any one plant. For example, few foundries carry on all the essential operations known to the modern foundry industry. Some are primarily jobbing, while others are production foundries. Likewise, in the machine-shop industry, all the ramifications of machine work are seldom found in any one modern machine shop.

DIFFICULTIES OF INDIVIDUAL APPRENTICESHIP SYSTEMS

Is it not possible that the fundamental reason for the general failure of apprenticeship can be attributed to this modern development of more specialized manufacturing? Can the average small machine shop or foundry of our day justify and make possible a training program worthy of the name? Take the case of a typical American manufacturing center. In this center, less than ten per cent of the metal-trades manufacturing plants employed more than a thousand men, and even these could not be called a general manufacturing industry. This ten per cent of the number of plants employed about forty per cent of all the mechanics. The other ninety per cent of the total number of plants employed more than sixty per cent of all the mechanics in that district. Yet this ninety per cent group of smaller plants could by no possible stretch of the imagination be conceived as capable of sustaining an apprentice-training system. It would not only be unjust to prospective apprentices, but it would be impracticable financially for these plants to establish an apprenticeship system of training the mechanics they required. One imaginable solution for this typical district would be for the larger plants with their greater facilities to train all of the skilled workmen required for the district. The smaller plants would then be users rather than producers of mechanics. The larger plants would train more mechanics than would be needed after they had become skilled workmen. However, this solution has never been approximated in practice. Until within recent years American plants have failed to train men enough for their own needs, and have supplied the shortage from the ranks of European immigrants. Recent legislation having cut off this source of skilled mechanics, it now has become necessary either to train native mechanics or become an inefficient and possibly bankrupt nation industrially. Even though faced with this unpleasant condition, we have heard that "apprenticeship is dead." It is asserted that it is impossible to train young Americans as skilled mechanics in the trades, so that some other form of training must be devised.

It is our purpose here to discuss the salient reason for this failure of American apprenticeship and to suggest the remedy. Apprenticeship that is worthy of the name is a possibility only in a manufacturing organization whose diversity of work and operation embraces an entire trade or group of trades. It will be totally ineffectual in modern industry if we organize apprenticeship in terms of the individual plant because the vast majority of modern manufacturing plants, particularly in the metal industry, do not carry on all of the essential operations that are necessary to constitute a trade in its vocational aspects. Rather, they are dependent upon many allied and subsidiary industries to make them complete manufacturing units.

Under these circumstances we cannot expect the old tradition of apprenticeship to live and flourish. A young man attaching himself to any but the largest organization is destined never to receive a complete and finished trade training. The plants themselves, in many cases, realize that they cannot justify an apprenticeship made up of the traditional four years of training. Many a small plant has in all sincerity attempted the regular apprenticeship system of training only to realize after years of failure not only the impossibility but the injustice of such an attempt.

The result of it all is the present situation. A few of the larger plants in each of our industrial communities are conducting regular and systematic apprenticeship-training courses duly organized and supervised. The great mass of smaller plants are either doing nothing by way of training their quota of skilled workmen or they are limping along on some makeshift with an incomplete schedule,

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and producing some of our "half-baked" mechanics. In other words, a few plants are making the effort to train the skilled workmen required in their respective industrial communities, while other plants are parasites, depending for the most part, on the community in which they are conducting their businesses. This is the general condition existing in American industry today.

NEGLECT IN TRAINING FOUNDRY APPRENTICES

While it is generally true that a few of the larger plants in the metal-working industry have been able to train and actually are training a skilled employee personnel, training for the foundry has been practically entirely neglected even in larger plants. Although it has been possible, in a plant whose manufacturing operations justified it, to make machinists and patternmakers and draftsmen, great difficulty always has been experienced in the training of molders and foundrymen. This has been true even in foundries doing a general jobbing business. The work presents, on the surface, a more disagreeable aspect and has therefore demanded greater resources from the organization in charge of the training work. Unfortunately the line of least resistance has been all too often followed. The training of foundrymen has been so neglected that, unless there is a change, we are well on our way to witness, within another decade, the extinction of the skilled foundry employee.

There is a remedy for this sad state of affairs in which modern industry now finds itself, if apprenticeship be conceived of as a community and not as an individual affair. Until all the plants representing any one trade or group of trades unite to coöperate in the essential and all-important business of training a sufficient body of skilled men necessary for their respective districts, apprenticeship will probably continue to be a failure and American industrial personnel will continue to degenerate. The small plants must be united to the larger in such groups as seem most efficient for the conditions under which they are working. Their united efforts must be applied to the problem of industrial training and the entire industrial district must be centrally directed in its apprenticeship activities. In other words, each industrial district must become a unit in its training work.

NECESSITY FOR COMMUNITY COOPERATION IN VOCATIONAL TRAINING

Schedules and programs of training must be so arranged that the smaller plants can assume such share in the training of the individual apprentice as their diversity of work and operation justifies. In a four-year schedule, and we are here mainly concerned with the problem of training men for trades, this may mean only six months in a smaller plant. It will always mean less than four years. The remainder of the time will be spent according to the prearranged plan in the larger or "mother" plant of the group.

The apprentice may begin his training in either the larger or the smaller plant. This is unessential. At the end of four years he will have had a completely rounded out, well-organized, and systematically supervised course of training in the trade he has determined to make his life work. This is the essential feature, and it is the one that is so often utterly impossible under the old-fashioned idea of making apprenticeship an individual plant affair.

To carry on apprentice training as a community affair, it is obvious that there must be a district organization whose sole business is to arrange and care for the proper grouping of plants, the supervision of apprentices within the group, the planning of schedules suitable for the group, and, finally, the interchange of apprentices at the proper time from the smaller to the larger plants and vice versa, as the demands of the schedule are to be met. But it means above all, and this is most essential, a spirit of coöperation, a spirit of frankness and solidarity among the plants representing a similar group of trades in an industrial district. It is this latter which must first be established in promoting a district apprenticeship. All efforts, no matter how well directed and intentioned, are bound to fail until this spirit of coöperation, only too frequently missing, has been firmly and definitely established.

THE MILWAUKEE PLAN

That the district plan for apprenticeship training can be successfully applied has been illustrated in Milwaukee, a typical industrial community. In diversity of product and operation a few of its larger plants embrace completely the trades they represent. The remainder, and by far the larger number of plants, are dependent upon allied industries for the completion of their operations and their products. Until a few years ago a number of the larger metal-manufacturing plants were training apprentices. A vast majority of smaller plants had long since discovered that they were unable to make apprenticeship an effective part of their activity. These latter were enjoying the fruits of the labor of the larger plants, whose individual efforts would, for the most part, have supplied their own needs. The result was that Milwaukee was an undermanned industrial city in its skilled personnel. In the training of skilled foundrymen it had failed almost completely.

A local metal-trades organization was formed and through it an efficient apprenticeship committee began to function. The question which immediately confronted this committee was: Shall Milwaukee consider apprenticeship as a community affair in which all plants, regardless of their size, will contribute their share, or shall it continue in the old manner which consisted largely of a few of the larger plants assuming the burden of training for the whole community? The answer reached was "Coöperation." The old individualistic idea of industrial training was discarded and apprenticeship was envisioned instead as a community affair. In five years a sufficient success has been achieved to justify the firm conviction that modern apprenticeship, to be successful, must fit modern industrial conditions.

OUTLINE OF THE PLAN

The plan followed in this district is as follows: Milwaukee's metal-trade plants are grouped in such manner that the proper number of smaller plants are allied with the larger plant for the purpose of carrying on an adequate program of industrial apprenticeship. Thus the smaller plants are made to bear their just burden in the training of a skilled personnel required to make the district a self-sustaining industrial center. A spirit of coöperation and solidarity has been established through the efforts of the apprenticeship committee which has made such fine coöperation in training possible.

A district supervisor of apprenticeship has been employed to carry on the district activities. It is his duty to care for the proper geographical grouping of plants, the establishment of adequate schedules of training, and the interchange of apprentices between the different plants. An apprenticeship policy has been laid down by the district apprenticeship committee. The director is responsible only to this body.

There are many other important and interesting features in the Milwaukee program, but the essential one, the one which above all others has made success possible, is the district feature. Apprentices are now being trained on a sufficiently adequate scale to make Milwaukee a self-sustaining and independent industrial community within a few short years. Moreover, and this is an outstanding aspect in the Milwaukee plan, apprenticeship in steel and gray-iron foundries has not only become a possibility but an actuality. Apprentices are now being graduated from three- and four-year foundry courses. These are the first cherished and long-looked-for fruits of this apprenticeship plan. Smaller steel and gray-iron foundries united with larger foundries to coöperate in this training work. Adequate courses designed to train molders and coremakers are being offered on this coöperative basis. This has not only made possible the training of a skilled foundry personnel but it has also brought about, for the first time, the active participation of the small foundry, no matter what its character of work, in the training program.

The range of the courses in all of the metal trades has been sufficiently varied to attract all types of young men, from those with a grade-school education to those who have completed professional-engineering training. The great need, however, is (and always will be probably) for the young man sixteen years of age whose vocation in life, for one reason or another, is to be some industrial trade. Significantly enough, the foundry courses have not only attracted those with a professional training and who are destined for executive positions, but those also whose education

has been limited to grade or high school. While other industrial communities have always experienced insurmountable obstacles in attracting young men to the modern foundry, the Milwaukee district, under the new plan, has not only had a sufficient number of applications for present purposes but has had a waiting list of young men anxious to enter upon the foundry business and learn it in all its interesting and varied features. This has been made possible by the coöperative group plan in which the individual apprentice has an opportunity to become acquainted with all the phases of foundry work.

ASSISTANCE GIVEN IN MILWAUKEE BY LOCAL EDUCATIONAL INSTITUTIONS

From its very inception the district program has been stimulated and aided by the splendid coöperation of the local Vocational School and the College of Engineering of Marquette University. The former, in its efforts toward the fulfilment of the district plan, has gone far beyond its mere legal requirements under the Wisconsin Apprenticeship Statute. This has made possible the excellent related trade training so necessary to modern apprenticeship. The technical foundations of a modern trade have been so vastly enlarged that it is impossible to present an adequate schedule of training unless sufficient time be devoted to imparting related technical information. This presents an added impossible burden to the smaller organizations incapable of bearing the financial burden necessary in the organization of proper trade courses. A vocational school whose central idea is apprenticeship cannot only supplement the apprenticeship work of the smaller plant, but it can also do this particular work more effectually than the larger plant. Much of the success of the Milwaukee district program is due to the excellent part played by the local vocational school.

Marquette University, in its coöperative engineering courses, has been a tremendous factor in the success of this entire program of apprenticeship. These young engineering students, spending alternate months in shop work of an engineering apprenticeship nature, have not only given an impetus to the whole program of training, but have by their presence given a prestige to apprenticeship which could scarcely have come in any other manner. The splendid coöperation of this institution has made much of the success of the district idea possible. In fact, it was only with the inauguration of coöperative engineering courses that apprenticeship generally took on a new lease of life in this district.

All apprenticeship activities in Milwaukee are district-wide in scope. Propaganda and general educational work are made a district affair. The coöperation of the public-school system has been secured and, through vocational guidance, the tradition of apprenticeship has been revived. Social and inspirational gatherings of Milwaukee metal-trade apprentices have helped to accentuate the benefits of the district idea. A publication is devoted solely to local apprenticeship activities, objectives, and aims. The individual plant is subordinated to the district always, and the district is supreme. The result is that apprenticeship is becoming generally effective and successful.

NATIONAL ORGANIZATION OF APPRENTICESHIP

It should be noted in passing that the district organization of apprenticeship must naturally lead to a national one. This is already taking place through the efforts of the National Metal Trades Association and the National Founders Association. A director of education has been appointed whose object it will be to promote a district apprenticeship program in all of our leading industrial communities.

Apprenticeship, to be completely successful, must be universal in extent. Hence the necessity of a national organization in which are centered organizational and promotional efforts necessary to coördinate, where that is essential, the work of the various districts and thus bring to complete fruition the apprenticeship idea.

Unless we are to become a sadly inefficient nation industrially, the industries themselves must assume the initiative and coöperate in the training of skilled workmen. The success of the district apprenticeship-training plan in Milwaukee appears to offer a solution to the problem of the rapidly diminishing skilled personnel in American industry today.

Training for Industry and the Public Program of Vocational Education

BY FRANK CUSHMAN,[1] WASHINGTON, D. C.

IT IS apparent that several different types of men are needed in modern industrial organizations. In general, all of the workers concerned with production in any given plant may be classified into six groups, as follows: (1) Executives, managers, and superintendents; (2) engineers and technical experts; (3) minor executives, including foremen; (4) skilled workers and apprentices; (5) semi-skilled workers, largely machine operators; and (6) ordinary labor.

THE FIELD FOR TRAINING

It is exceedingly difficult to find jobs in industrial organizations that can be performed satisfactorily by persons who have had no instruction or training whatever. In view of the fact that all of the above groups of workers must possess to some degree special knowledge and skill in order to perform their work acceptably, the question naturally arises, To what extent has any definite program been established for the purpose of giving the members of the six groups named above the training which they need?

So far as the executives, managers, and superintendents are concerned it must be admitted that there is practically no agency which offers the specific training that these men need in connection with their work. For the most part such men grow up in an organization and pass through a sort of informal apprenticeship, during which they acquire on the job the special knowledge and skill which they need as plant executives.

In the case of engineers and technical experts the situation is quite different. For many years engineering schools and colleges have been training technical men and engineers, and at the present time the means for training and maintaining a sufficient supply of engineers and technical men is adequate, at least in part, to meet the demands of industry. Experience has indicated quite strongly that a technical education does not necessarily constitute the best type of preparation for an executive. The technical expert is trained to deal with *things*. The executive has to deal principally with *men*, and until very recently little attention has been given in technical and engineering schools to the problems of personnel administration and human relations in industry.

Furthermore, in attempts that have been made to train industrial executives too great an emphasis has been placed upon pre-employment training. Unquestionably, in education and training as well as in other activities there is a point at which the law of diminishing returns becomes operative. The custom of training young men for industrial positions of high authority and great responsibility in advance of any experience in industry itself is open to serious question, even if it were possible to give really effective training for such positions on a pre-employment basis. Engineering schools and colleges could render a great service by making it easier, through the recognition of successful experience in industry as adequate preparation for advanced instruction and training, for persons who have demonstrated their ability to make good on the job to secure, when they need it, the specific training that will prepare them for the opportunity just ahead. Under present conditions most men have to prepare themselves for advancement by their own efforts inasmuch as in most cities there are no definite opportunities of an organized character for them to get this advanced training just when they need it. Industry is primarily interested in results. It has often been criticized unkindly for promoting men to positions of responsibility and authority more upon the basis of evidence of ability to get results than upon the basis of formal education, academic and technical preparation.

The training of minor executives and foremen has, until within the last five or ten years, received scant attention. Foremen are generally selected and placed on the job in charge of the work of others without any definite preparation other than the practical experience which they have secured in the shop. On the whole, this statement is true with regard to other minor executives in industry, such as employment managers, welfare directors, and departmental superintendents.

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For the most part our industrial men have given very little attention to the development of thoroughly trained skilled mechanics. There are of course notable exceptions to this, but it is generally true that most employers have given little or no thought to sources of supply for skilled workmen.

Coincident with the development of specialized methods of manufacturing the demand has been great for large numbers of semi-skilled workers. This group includes all persons in manufacturing establishments who are machine tenders and operators in contradistinction to skilled workmen. The problem of training such workers has been taken care of in part by special training departments and by vestibule schools. There is still, however, a great number of industrial plants where the training of semi-skilled workers is left almost entirely to the foremen.

It is ordinarily assumed that common labor is entirely unskilled and that no special training for laborers is required. This assumption is justified only in part, however, because many of the jobs performed by laborers offer greater possibilities for training.

From this discussion it will be noted that, with the exception of engineers and technical experts, most persons employed in industrial occupation learn to do their work by the method of absorption on the job. In some cases there is a sort of informal apprenticeship. In the skilled trades there is, at least in theory, a real system of apprenticeship. But aside from these exceptions the procedure which is ordinarily followed consists of little more than learning to do jobs by the method of trial and error.

Training Problems always Present

It follows, therefore, that practically every industrial plant has training problems, which may or may not be recognized. Wherever persons are learning to do jobs, vocational training is going on. This is true whether the training is carried on by the "pick-up" method in plants where the problem is not recognized, or whether the training is going on by some organized method in plants where an attempt is being made to deal with the training problem.

In general, there are four type situations which exist in industry today. The first type situation is illustrated by an industrial organization which does not recognize the existence of any training problems and which no training of any kind is going on. Such an organization necessarily depends upon other organizations engaged in a similar line of work to train its men. A second type situation is where no training problem is recognized by the management but some training is going on. An illustration of this would be a plant where, although the management does not recognize any training problem, some of the more ambitious men in the organization are of their own initiative taking correspondence courses or attending public evening schools. A third type situation is an industrial plant where the existence of a training problem is recognized but where nothing is being done to meet the situation. An illustration of this third type is a plant that has operated for a long time without giving any attention to efficient training methods but has been suddenly brought to a realization of the fact that very few industrial organizations can continue to operate successfully by letting other agencies train men for them. The fourth type situation is where a training problem is clearly recognized and definite provision has been made for taking care of the problem by the most efficient methods. There is a rapidly increasing number of industrial plants of this type.

Three Groups into Which All Candidates for Training may be Classified

All persons who would be affected by a program of education and training in an industrial organization may be placed in one of the following three groups: (1) Those who have none of the special knowledge and skill necessary to do the work which is to be done; (2) those who have part of the special knowledge and skill required to do the work; and (3) those who have the knowledge and skill necessary to do the work acceptably.

A program of education and training should therefore be organized with due regard to the particular needs of the groups of persons for whom it is intended. For those who have none of the special knowledge and skill necessary to the performance of a given job or series of jobs the instructional work should be definitely organized for the purpose of having the learner reach an acceptable standard of performance in the least time and at the least expense. Most of the work of vestibule schools is intended to deal with persons who would be classified in the first group, with perhaps a few from the second group. For persons who have a part of the knowledge and skill which they need on the job, the problem is to give them supplementary training for the purpose of making them better qualified to do their work. For those who have at least the minimum knowledge and skill necessary to do their work the objectives of the training would be quite different from either of those previously mentioned. For the most part persons who would be included in this third group are foremen and other minor executives who have developed the ability to do their work acceptably without any definite training for their special duties.

Objectives for a Program of Plant Education and Training

The objectives of educational work in industrial organizations are often not clearly defined. In general, the objectives have to do with general education, improvement of morale, and increased efficiency on the job.

Very often courses which are in fact nothing more than general education in character have been introduced into industrial plants because of the acceptance of one or more fallacies: (1) That any addition to one's general education may be expected to result in a better performance on specific jobs, and (2) that general development of the faculties will increase one's ability to perform a specific task. Many attempts to conduct educational work in industry have been based upon little more than the assumption that education in the abstract is a good thing, and that any educational work and study undertaken by its employees is a good thing for an organization. While such attempts to promote efficiency on the job undoubtedly show little or no tangible results of a specific nature, it is probably true that this sort of work tends to some extent to promote the morale of the working force. Considerable inefficiency and wasted effort, however, is bound to result where a program is set up by the hit-or-miss plan without a definite determination of the purpose of the training and the bases upon which the program is justified. Specific vocational training may be either initial or trade extension in character. Vocational training yields tangible results when it is organized to accomplish a definite purpose.

Many training courses which are supposed to have a vocational objective do not function in the most effective way because of the acceptance of certain fallacies, such as (1) that instruction concerning general principles will fully equip a person to do specific things; (2) that employees, including foremen, are able to make their own application of general principles; (3) that the possession of information about doing a job results in ability to do the job.

In addition to the above fallacies, which are more widely accepted than they should be, much of the training which is supposed to be vocational may be discounted because the instruction deals with information which the men may need in case they ever become superintendents or managers, but for which they have little or no use on their present jobs. There is a wide difference between giving a man the training he needs to make him thoroughly efficient on his present job and filling him partly or wholly full of information regarding some job other than the one which he has. One of the first steps in preparing a man for promotion is to bring him up to a high standard of performance on his present job. As a rule, promotional training as a plant activity is justified only when there is a definite opportunity for promotion. Too much promotional training without an opportunity for advancement is quite certain to spread dissatisfaction.

Determination of a Program for a Given Organization

The kind of program which should be undertaken by any given plant or industrial organization would depend in general upon two main factors, namely, the type of organization, and the experience and training already possessed by those whom the program is designed to reach and benefit.

It is important to consider the type of organization, especially where any form of training is to be introduced for the foremen and other minor executives. A foreman-training course for a plant which is highly functionalized should be very different from such a course in a plant which is functionalized only to a small extent

or not at all. The qualifications of those to be served by the program should influence to a great extent the nature of the training work to be done. In certain organizations the training of "green" or inexperienced operators or semi-skilled workers is one of the most important training problems. In other organizations, where there is little turnover, this problem does not exist at all. In almost every type of organization training courses for minor executives have proved to be of value. This is true because for the most part these men have had no organized training whatever for their special duties. Such men do not need instructions as much as they need to be brought to a realization of their responsibilities and to have their knowledge of their jobs better organized.

SUCCESS FACTORS

Many programs of education and training for one or all of the groups previously referred to have failed to produce the expected results. Among the reasons for this failure may be mentioned: (1) The courses were too largely informational in character. As stated before the possession of information alone does not constitute preparation for doing a job. (2) The material for instruction was not organized and presented in the most effective way. Such results occur when too much reliance is placed upon general principles, and also when the habits of thought of the members of the group are not recognized and appreciated. (3) Much of the training, especially for foremen, has been promotional in character rather than the sort of training needed to increase efficiency on the job. If improvement on the job is the objective it may be assumed that results will be secured in proportion as the work is set up to meet the specific needs of the men.

Another very important factor in the success of any educational activity is the instructor. For job training and trade extension work it is absolutely necessary to have instructors who are, first, thoroughly competent and expert workers, and, second, who have the ability to teach effectively what they know. For foremanship conferences it is necessary to have a man who knows how to use that particular method of teaching and who understands the importance of using a developmental rather than an informational basis in educational work with experienced men. Where foremen are utilized as instructors for job training and for trade extension training the most important part of the educational work of the plant is the training of these foremen to function effectively as instructors. If an educational program for the foremen and minor executives is to be inaugurated, experience up to date indicates that the work should be in charge of the educational director of the plant or some minor executive not directly in authority over the foremen.

TRAINING COSTS

As has been stated before, training costs money. This is true whether the problem is left to work itself out without any special attention being paid to it or whether there is a well-organized training department. Organized methods of dealing with the training problem in industry are justified in proportion as they serve to cut down the cost of training, thereby reducing what has been termed "concealed overhead."

The cost of training will be reduced in proportion as the methods of selecting candidates for training are efficient. To illustrate, where six persons are partly trained for a job before one is found who is able to do the work satisfactorily and who will stay on the job, costs are increased. Training costs will also be lower in proportion as the training is well organized. It may be pointed out that it is entirely possible to have the training well organized in an industrial plant without having a separate training department. This has been done in a number of cases by making foremen responsible for training men in their own department and through coöperation with the employment manager, thus accomplishing all the desirable results that a separate training department is supposed to secure. Furthermore, efficient methods of training new and old workers may be expected to result in reducing accidents, the amount of second-quality product turned out, damage to equipment, breakage of tools, and spoilage of material.

As has been stated before, the training of engineers and technical experts is well provided for by engineering schools, colleges, and universities. Within a comparatively short time a number of higher institutions of learning have addressed themselves to the problem of training executives for industry. A recent investigation by the National Industrial Conference Board, however, shows that for all the industrial plants covered by a recent survey only 17 per cent of the plant executives had any definite preparation for their work. This means that 83 per cent of all executives in these plants had developed the necessary ability to do their work by serving a sort of informal apprenticeship where they probably learned most of what they needed to know by absorption and from their own mistakes or the mistakes of others. Eliminating, therefore, from consideration for the present the problem of training executives, engineers, and technical experts, there remain four important groups of people in industry for whom, until very recently, little training has been organized. These four groups are: (1) Minor executives and foremen, (2) skilled mechanics and their apprentices, (3) semi-skilled workers, and (4) unskilled labor.

THE RESPONSIBILITY FOR TRAINING

The next question that naturally arises is, What agency or agencies should provide educational opportunities for these four groups and how should the cost of their education and training for industry be distributed? In trying to arrive at a definite answer to this question a few fundamental facts should be considered by those who are responsible for setting up any type of agency or organization for dealing with this problem, whether public or private.

In the first place, the general public ultimately pays the bill, regardless of whether the training for industry is conducted by public or private agencies. As has been stated, training costs are sometimes recognized, but often they are submerged in what is known as "concealed overhead." All training costs add to the cost of production, which in turn are reflected in prices charged for the product. Certain phases of this problem seem to be a responsibility intimately associated with our system of public education; other phases seem to have a very remote relationship to the public program of vocational education. In general it may be stated that the guiding principle should be to have this training for industry conducted in the most efficient way. The public program of vocational education cannot and should not attempt to carry the whole load. For the best interests of society the public should not permit industry to carry the whole load because in this country all workers are citizens of the United States and in a democracy like ours the nation can not afford to leave the education of its workers wholly to industry.

THE PUBLIC PROGRAM FOR VOCATIONAL EDUCATION

As a result of the passage of the National Vocational Education Act (or the Smith-Hughes Act) a public program of vocational education has been actively promoted for more than seven years. Every one of the 48 states now has a board which is directly responsible for the development of the work within the state. In the industrial field the public program has reached to some extent every type of industry. During the year ended June 30, 1924, more than 400,000 persons were enrolled in trade and industrial classes which received Federal aid. Approximately 90 per cent of this entire number were employed workers of all ages, the remaining 10 per cent representing the enrollment in full-time trade schools.

This publicly supported program of trade and industrial education includes many lines of service, such as (1) the full-time unit trade schools, which meet in part the needs for apprenticeship training in the skilled trades; (2) coöperative part-time schools, which operate by alternating time in school and time at work on the week-about or two-weeks-about plan; (3) part-time schools for apprentices, which provide from four to eight hours of trade instruction per week to supplement the practical experience which the apprentices secure on the job; (4) compulsory part-time schools, operated in 24 of the states where all minors of certain ages who are not in the regular schools are required to attend school from four to eight hours per week for thirty-six weeks per year; (5) evening trade extension schools for persons over sixteen, which offer instruction supplementary to the daily employment of persons employed in industry; and (6) industrial-teacher training courses, which offer opportunities for experienced workers in industry to prepare themselves as instructors of trade subjects.

In addition to the above, the Federal Board for Vocational Education and many of the state boards have rendered a great deal of service to industrial concerns in assisting those organizations which prefer to conduct their own training programs to make their work more efficient and also to promote greater coöperation between industry and the public schools. Coöperation between industry and the public schools is unquestionably the great goal to be achieved. Those who are promoting the public program of vocational education are primarily interested in rendering a service which has a great social and economic value. They are not attempting to dominate the situation and to displace legitimate educational programs conducted by industry itself, nor to interfere with such work. As the program grows and develops, the lines of demarcation between those activities which should be fostered and supported by public schools and those which belong to industry itself are becoming more clearly defined. To the extent to which real coöperation is realized and industry and the public program of vocational education are brought more closely together the work will be more effective and will to an increasing degree accomplish the important purposes which were so clearly set forth in the 1914 report of President Wilson's Commission on National Aid to Vocational Education.

Discussion of Papers on Education and Training for the Industries

W. F. TURNBULL.[1] In Germany, this summer, I was in the office of the Secretary of the German Engineering Society, and he said, "Now, here is a table that shows what Germany did before the war, pamphlet after pamphlet, reports, discussions, most of them generalities." Then he turned and said, "This is what we have done under pressure of the war."

They had gotten together a mass of concrete material under the guidance of a council composed of delegates from the national educational system, also from the industries and from the German Engineering Society. There are three kinds of material. One is a mass of stereopticon slides, amounting to several thousand, covering every branch of elementary physics and engineering operations, which can be used for the education of the public and also apprentices in the apprentice schools—which are mostly conducted by the industries themselves.

The second is a vast group of material in the form of concrete problems, some of them in drawing and design, some of them in production, which have been gotten together in this way: Every industrial plant was asked to contribute examples of what it considered the most instructive problem or idea to be presented to the apprentice. Thousands of these were accumulated. They were sifted over by this council and the best of them were selected, amounting to about one thousand sheets. Some of them are arithmetical problems, some are drawings of miscellaneous kinds. These were sorted out by units, each unit representing a particular phase of a particular occupation, and they were subdivided, about twenty-five or thirty sheets in each. They were then traced on heavy tracing paper with the title in the corner, a blank space being left for the name of the firm. They are handled in this way: Any particular firm that wishes a set of these problems for their apprentice class gets from the office of the German Engineering Society one of these sets of tracings. They block in their own name. Then they blueprint them and sell the prints to the apprentices, who naturally associate the name of that firm with these problems. Then they are used in the apprentice schools.

The third class of material is for the benefit of the skilled workers in the industry. It consists partly of similar problems and partly of wall charts, mostly based on the idea of the right and wrong way to do a thing, so that even the journeyman is enabled to learn the method used by the most skilled man in all Germany, theoretically, since this material was collected from all over the nation.

It would take an hour to describe all of this in detail, but I think it is a magnificent example of national coöperation of the industries, the engineering and the national department of education.

[1] New York University, University Heights, New York, N. Y.

HUGO DIEMER.[1] I have been wondering, in connection with the Milwaukee plan, whether the organized trades, the labor unions, took part in the coöperation, or whether they were invited to take part, and what their attitude is toward it.

MR. FROMMELT. Milwaukee is essentially, in its metal-trade activities, an open-shop district. The unions, therefore, have not, in the sense described in the paper, coöperated in this plan. However, they have given very satisfactory and very splendid coöperation to the local vocational school in the other lines in which they are active in that district.

F. E. MCCABE.[2] I would like to ask Mr. Frommelt what wage scale for apprentices has been generally agreed upon in Milwaukee. I find, in dealing with the apprentices that I have had, that it is necessary to satisfy the parent as well as the boy, and that very often the parent desires his boy to earn the most possible. It is probably essential in many cases. On the other hand, the boy, too, has the inducement before him of higher wages, probably through some piece-work system which will enable him to earn two or three or four times as much as he would earn in working as an apprentice. It seems to me that the wage question is a big one in connection with apprenticeship training, and that we haven't given it proper attention. I would like to hear some expression not only from Mr. Frommelt, but from others on that particular point.

MR. FROMMELT. Significantly enough, wages are very seldom discussed in connection with the Milwaukee plan, not that we do not want any one to know what they are, but simply because they are not the essential thing in an apprenticeship system.

The Milwaukee apprenticeship committee laid down the following rates: Boys coming from grade schools, 16 years and over, going into machine shop and pattern shop, start out with 18 cents an hour. There is an increment every six months, and they go on from 18 cents to 22 cents, 26 cents, 28 cents, 30 cents, and 35 cents. In the foundry there is a 25 per cent increase for all of those schedules. They start out at 22½ cents an hour and go to 27½, 29, 30, 32, 35, 38, and 40 cents.

Older boys, still under 21, who had considerable experience in industry but who had seen the folly of going out and getting a job catch-as-catch-can, on the basis of getting a little more money, and then returning to serve an apprenticeship, start at 35 cents an hour; and the increments go up by one or two cents every six months until they reach 45 cents.

High-school graduates who go into the machine shop, foundry, pattern shop, or drafting room, start at 35 cents, and by a few cents' increment each six months, arrive at something like 45 cents. I don't remember the exact figures.

Coöperative university apprentices from the local university start out at 30 cents an hour, are increased by one-cent increments to something like 45 during their five years of engineering apprenticeship. Graduates coming from the universities, of which there are quite a number in the city of Milwaukee, quite generally are paid on the basis of 45, 50, 52½ and 55 cents an hour during a two-year apprenticeship. It has become quite common to give boys coming from grade schools a four-year apprenticeship, three-year for high-school graduates, and two-year for university graduates.

The parents of the boys referred to by the questioner are vitally interested in apprenticeship, but if apprenticeship must be sold to them on the basis of the wages paid to the apprentices and not on the value of the training, the parents will never be satisfied.

The tradition of apprenticeship must be revived in our industrial committees. This we have done to some extent in Milwaukee, as I have indicated in the paper, through contact with the public schools, vocational-guidance work, and vocational-guidance departments, through the local vocational school, and finally directly through the parents of the boys who are regularly indentured apprentices in our Milwaukee plants, by gathering them together three or four times a year and directly or indirectly bringing to them the message of apprenticeship.

Each individual plant in addition of course keeps the parents

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[2] Factory Supt., The Grables Mfg. Co., 6565 Broadway, Cleveland, Ohio. Mem. A.S.M.E.

of its apprentices informed directly as to the progress or lack of progress of their apprentices, and the parents, at least in the case of the organization with which I am connected, are always called in before the apprenticeship contract is signed. The whole apprenticeship is explained—the nature of the contract—and if necessary the parents are taken through the plant.

D. C. JACKSON.[1] I would like to ask Mr. Frommelt what is the character of the supervision which a central organization gives to these apprentices who apparently are indentured in such a fashion that they do not remain continuously in one works throughout their apprenticeship.

MR. FROMMELT. The supervision generally comes from the mother plant, the larger plant, which has a half-dozen or more smaller plants grouped about it. A rather elaborate organization for training is set up in the larger plant. That organization takes care of the supervision of the apprentices not only in its organization, but in the smaller organizations surrounding it.

To a great extent the work of the central organization, the district apprenticeship committee, and the district apprenticeship director is promotional and seeing to it that the apprentices are properly interchanged between the smaller plants and the larger plants in each group. The supervision of the district director does not go much farther than that.

The arrangement within the group is that the apprenticeship organization of the larger plant will take care of all the detail work, and the smaller plants remunerate the larger plant for it in some way and on some equitable basis.

C. W. CROSS.[2] The subject of apprenticeship is interesting to the members of this organization as it provides the only reliable method of training for recruiting. It is conceded that the best results in apprentice training can be accomplished only by a plan embodying instruction in the standard practices of the railroad company, and entirely under the control of the officers and administered by them. The graduate is thus thoroughly drilled in the company practices. It is from the rank and file that we always have and always will develop leaders. Many graduate apprentices are still in the service as workmen or supervisory officers.

Officials have declared that preference may well be given to graduate apprentices when selecting men for promotion, as they have been found to be competent. Promotion from the ranks inspires loyalty. Never was there so great a need for skilled mechanics as there is today, but we cannot develop real mechanics unless there is a definite and adequate plan of training adopted and rigidly adhered to. A thorough course of training for each trade must be laid out and some one must be responsible for seeing that each boy is carefully conducted through the course. There must be a definite amount of school instruction in order that the boy may be given a thorough understanding of the underlying principles of the job.

Means must be provided to insure thorough training of the apprentices in the shop work, by the use of shop instructors who devote their entire time to the instruction of the apprentices, directly on the work in which they are engaged in the shop. The department foreman cannot spare the time for detail instruction of apprentices as he is fully employed in the duties of administration of his department. It has been demonstrated that the use of a shop-instructor as indicated, results in a material increase in output, and is therefore immediately profitable to the railroad company, as well as ultimately beneficial in providing a group of well-trained and well-intentioned graduate apprentices to fill the places of their elders, retired by age or other natural causes.

This plan of apprenticeship training is not philanthropic, but is a good business investment, which has been found to be mutually profitable. It is therefore entitled to consideration by those who wish to adopt a method of recruiting that will be much to their advantage.

The New York Central Lines plan of apprenticeship is well known to the members of this association. It follows closely the methods suggested by George M. Basford in a paper before the American Railway Master Mechanics Association in 1905. It was described in the *Railway Age* in 1907. In 1906 the system was installed on the New York Central Lines and has continued with increasingly beneficial results.

There are three grades of apprentices: regular, helper, and special. Regular apprentices are boys 16 to 21 years of age, having a high-school education or equivalent, and in good health. Schools are maintained at the shops, six mornings per week. Each apprentice is given instructions in mechanical drawing, shop mathematics, physics and related subjects, during two periods of two hours each per week. Attendance is compulsory, and under pay, but the minimum requirements are not severe.

It has been realized that many boys who have not had much early education, still have good intentions, and respond promptly to a genuine opportunity to improve their condition and provide for the future by attending the schools. The course in each of the mechanical trades is four years in shop and school. The shop instructor supervises the movements of the apprentices in the shop, gives them instructions in the proper methods to follow and arranges for them to be moved in accordance with the schedule established for each trade. The shop instructors do not assign work, but instruct the apprentices in the work which the department foreman has assigned to them.

Helper apprentices are young men 21 to 30 years of age, in good health, who have had two or more years continuous experience as helper in the shop from which application is made, may be given one year allowed time and serve a three year course. Attendance at the school is optional for helper apprentices, however, many of them do attend. The shop instructors also look after the progress of the helper apprentices and many of them become satisfactory workmen.

Special apprentices are young men 18 to 26 years of age who are graduates of mechanical engineering courses in colleges and have good health. They are placed on the regular work in the shops and assigned to special work on tests, and selected duties, as required. These men do not attend the schools.

In making selection of apprentices, the sons of employees are preferred, although others are also taken. In this connection I wish to quote the last paragraph of the admirable paper on apprenticeship which was presented by Mr. John Purcell before the June, 1923, meeting of the American Railway Association at Chicago:

> Railroads should make and promote their own men and not depend upon other roads to furnish them. The thorough training of apprentices should have the backing and support of the chief mechanical officer, for it insures him of having not only skilled mechanics for the shop, but of having men trained and qualified to fill any position of a supervisory nature that may become vacant in his department. As a matter of fact, every officer owes it to his company and his superior officer to have men trained and qualified to fill any position that may arise. He should have some one under him thoroughly qualified, familiar with the property, and the rules and regulations, trained and ready to take his position whenever the necessity arises

Relation of Technical Education to Industry

THE relation of technical education to industry is a problem of interest to industry, to educators, and to graduates and students of technical colleges. Because of the feeling that there is a maladjustment between technical education and the life for which it is supposed to fit, the National Industrial Conference Board has planned a series of studies to determine what use is made of technical graduates at the present time by a number of the more important basic industries and what is needed better to adjust education to the needs of industry.

When the entire series of studies is completed, the findings will be analyzed, compared and published by the Board in a composite report on Technical Education and American Industry. In that report specific points will be discussed at length, with separate chapters on each of the industries studied.

A survey of the paper and pulp industry was the first study made. The basic material which comprises the paper and pulp survey was provided by 156 companies which are distributed throughout the country.

A copy of the report giving a summary of the results of an investigation of technical education in relation to the paper and pulp industry may be obtained from the National Industrial Conference Board, New York City.

[1] Prof. E.E., Mass. Inst. of Tech., Cambridge, Mass. Mem. A.S.M.E.

[2] Supervisor of Apprentices, New York Central R. R. Co., Motive Power Dept., New York, N. Y.

Progress in Steam Research

THE third annual session on Progress in Steam Table Research was held on Wednesday afternoon, December 3, during the Annual Meeting of the A.S.M.E. Dr. A. M. Greene, Jr., of the Steam Table Research Fund Executive Committee, presided, and progress reports on the various phases of the research were presented.

George A. Orrok, Chairman of the Steam Table Research Fund Executive Committee, reported on general progress, on the financial status, and on some new steam tables which had recently come to his attention, and predicted that inside of two years the Committee would have sufficient data to be fairly well along with the formation of the steam tables which it is striving to prepare.

R. V. Kleinschmidt, of Harvard University, told of the completion of the experimental work on the Joule-Thomson effect, and said that formulations from the data were not ready as yet.

F. G. Keyes, of the Massachusetts Institute of Technology, reported that difficulties in the leaking of the nickel bomb to be used in the research on the pressure, temperature, and volume relations had finally been overcome by the construction of a new bomb from a new piece of nickel. He described his apparatus and methods, and said that work of actual experimentation would start at once.

N. S. Osborne, of the United States Bureau of Standards, reported progress on the work undertaken at the Bureau in collaboration with H. F. Stimson. Dr. Osborne had with him for examination the calorimeter which had been developed for the work to be done at the Bureau of Standards. He hesitated to make predictions about future progress and did not wish his estimate to be construed as a promise, but said that he thought the apparatus would be ready for assembly in July and that by the next Annual Meeting he could report that the observation of data was under way. Dr. Osborne also presented a paper entitled Direct Measurement of the Heat Content of Superheated Steam, which will be found in the Mid-November issue of MECHANICAL ENGINEERING, vol. 46, no. 11a, p. 808.

Harvey N. Davis discussed the difficulties encountered in making formulations from the new data obtained by the Harvard experiments, and was followed by J. H. Keenan who had been assigned by the General Electric Co. to assist in the work of making the computations. Mr. Keenan's discussion will appear in the March issue.

The various reports presented supplement those given last year and published in the February issue of MECHANICAL ENGINEERING, vol. 46, no. 2, p. 81. The reports on this year's progress follow.

Report of Executive Committee of the Steam Table Research Fund

GEORGE A. ORROK, Chairman of the Steam Table Research Fund Executive Committee, reported as follows:

At the last meeting of the Steam Table Fund it was reported that $27,225 had been collected and subscribed, and that by October 1 this amount would be entirely expended. It was also stated that within a short time we would commence a campaign for additional funds. The work lagged a little last year for a number of reasons, and on account of the general market outlook it was determined to wait until business conditions would be more propitious before starting a campaign for funds. In September we took up this work again, and since that time have received several subscriptions of varying amounts, totaling $2850, with promises of three more subscriptions of good amounts. The total receipts to date are $30,075, leaving a balance on hand as of December 8, 1924, of about one thousand dollars. The work at Harvard University and at the Massachusetts Institute of Technology, the bills for which have not yet been received, will wipe out the balance and about four thousand dollars more, which we hope to have by the first of the year.

The work at Harvard University, which was the first we put under way owing to the fact that the apparatus had already been developed, was practically ended in September and the rest of the time has been spent in computation.

At the Massachusetts Institute of Technology the work was held up as reported earlier in the year due to a defect discovered in the pure-nickel bomb. A new piece of nickel has been secured and the new bomb has been completed and put in operation.

At the Bureau of Standards we were able to put on a new man, and the work there has been progressing satisfactorily.

Within the last two months, four sets of steam tables that I have never seen before have been received, They are very interesting steam tables, not agreeing with themselves or with other tables.

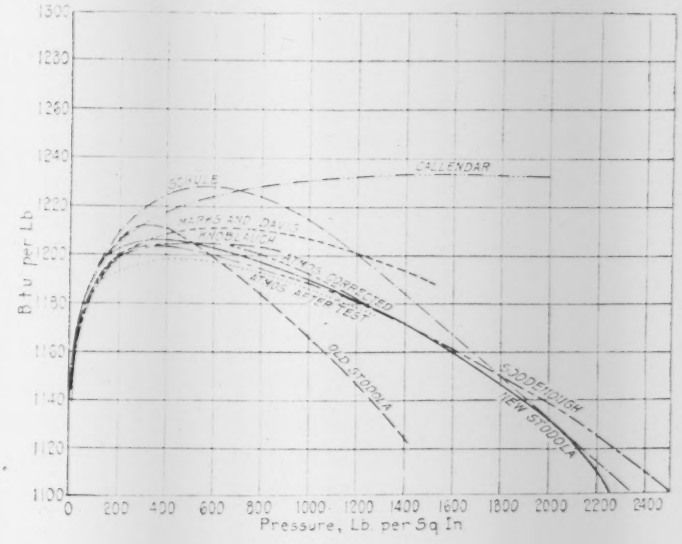

FIG. 1 TOTAL HEAT CONTENT OF SATURATED STEAM AT VARIOUS PRESSURES AS GIVEN IN DIFFERENT STEAM TABLES

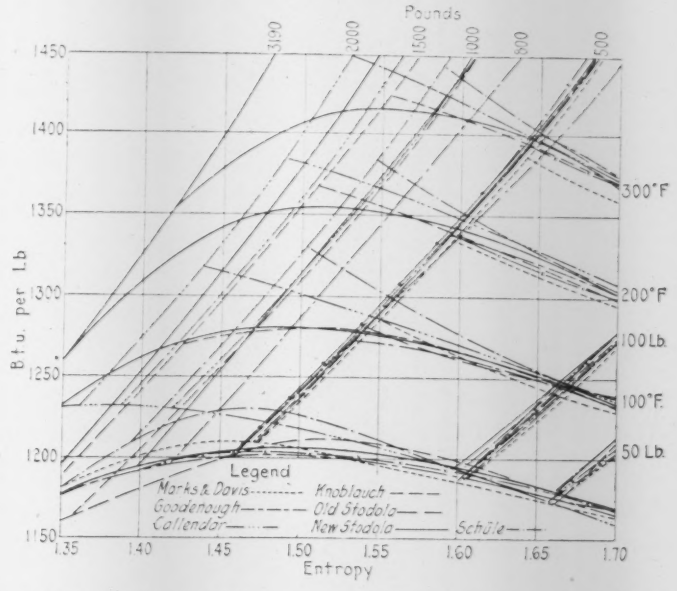

FIG. 2 COMPARISON OF MOLLIER DIAGRAMS FOR SUPERHEATED STEAM

The total heats of saturated steam are plotted in Fig. 1, and the divergencies are seen to be as wide as 150 B.t.u. out of 1250 at a pressure of 2000 lb., which is the limit of the new Callendar table. Stodola, Goodenough, and Schüle seem to be within range of one another. Marks and Davis and Knoblauch make higher curves, while Callendar is much higher than any one else. Plotting the Mollier diagram from these tables, it will be seen in Fig. 2 that the divergence is smaller, although the divergence of the trend of the curves is still large. Comparing the available heat between 700 deg. fahr. temperature and 29 in. vacuum for various pressures, the curves of Fig. 3, while not widely divergent, still show uncertain-

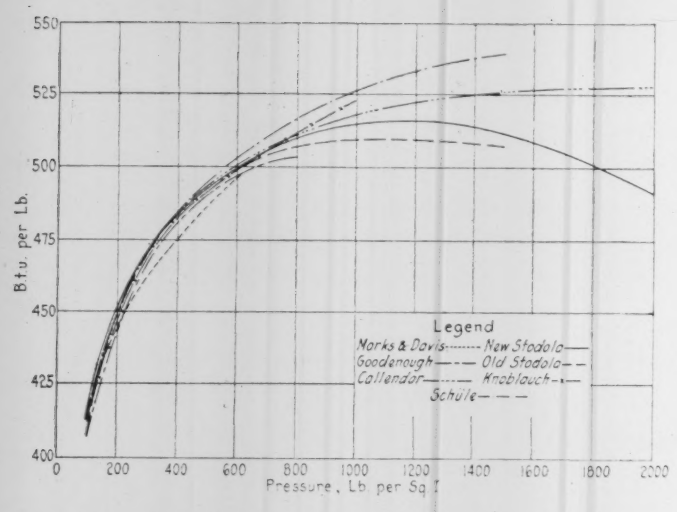

Fig. 3 Available Heat Drop from 700 Deg. Fahr. Total Temperature to 29 In. Vacuum

ties to cause concern at 400, 500, and 600 lb., while at 1200 lb. the divergencies are very large.

Report of Progress in Steam Research at Harvard University

By R. V. KLEINSCHMIDT,[1] CAMBRIDGE, MASS.

IT GIVES me great pleasure to be able to report to the Committee and the Society that the Joule-Thomson measurements which are being carried on at Harvard have been completed so far as the

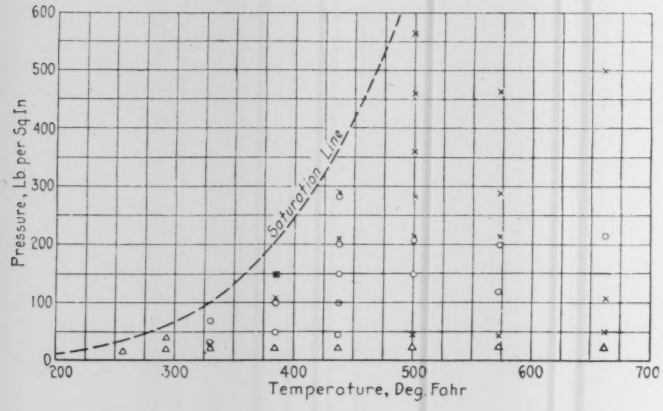

Fig. 4 Pressures and Temperatures at Which Harvard Observations Were Taken

actual experimental work is concerned. The original program laid out for this work, which has been completed, covers the field up to 565 lb. per sq. in. pressure and from 125 deg. cent. (257 deg. fahr.) to 347 deg. cent. (657 deg. fahr.). Unfortunately there has not been time to formulate the results obtained in their final form, but it is possible to present diagrams showing the trend of the observations.

The actual experimental points indicated in Figs. 4 and 5 are as accurate as can be obtained from the data. All checking of computations has been completed. The values of the Joule-Thomson coefficient in Fig. 5 are the result of about three hundred and fifty separate runs, each of which would give all the data necessary for a measurement of the coefficient, except for heat leak. The correction for heat leak is obtained from a group of runs all at the same pressure and temperature but with different amounts of steam flowing through the apparatus. As each run involves from fifteen to thirty readings of each of the quantities involved, it is estimated that in the course of the work there have been taken about ten thousand pressure-drop readings and sixteen thousand readings of temperature difference.

Fig. 4 shows the pressures and temperatures at which observations have been taken. When the work was started there were grave doubts as to whether it would be possible to get the highest temperature line at all as it is above the flash point of the best oil that could be obtained. Although we did not fill in many intermediate values on this line, those we have are so good that the line is as well determined as any. The circles in Fig. 4 are the points taken during the first year (1922), the crosses those taken during the second year, and the triangles those taken during the past year. We thought last December that the runs taken during the first year were less accurate than the later ones because the heat leak in them is very large. We have now developed a satisfactory method of handling this large heat-leak correction so that all the points are sufficiently accurate to be plotted as final results.

Although it looks as though relatively little work had been done this year as compared with other years, actually the three lowest temperature points were harder to obtain than any other six points on the whole diagram. We ran at 293 deg. fahr. and 40 lb. per sq. in. pressure for three weeks in an attempt to get conditions sufficiently steady close to saturation. The low-pressure points out in the high-temperature region were taken in order to fix the low-pressure ends of the lines in case the first year's work was not capable of being corrected.

Fig. 5 shows the values of the Joule-Thomson coefficient as measured at various pressures and temperatures. The three low-temperature points, which are relatively poor compared with the other runs, are sufficiently accurate because the range of pressures over which we have to integrate to get total heats is so small in this region. The low-temperature points are difficult to get because they are close to saturation and it is difficult to keep moisture out of the apparatus without getting too much superheat. The low-pressure points are difficult to get because of the large volume of the steam, making it necessary to use a small mass flow of steam.

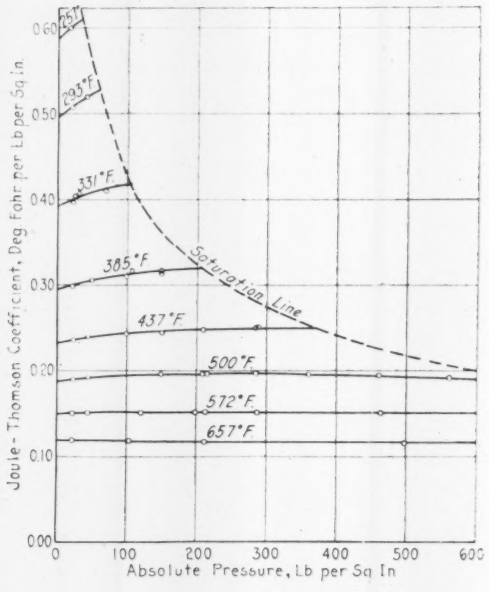

Fig. 5 Values of Joule-Thomson Coefficient at Various Pressures and Temperatures

This means that variations in the bath temperature and errors in the heat-leak correction make large errors in the final values.

The curve at 500 deg. fahr. is probably the best curve of the lot and is well determined over its entire range to about 0.3 per cent. In general, it may be said that all except the lowest pressure points, at temperatures above 400 deg. fahr., are good to better than 0.5 per cent, and that all the other values are good to within 1 per cent except the three lowest temperature points, which are good to about 2 per cent. These do not seem like high accuracies, but if one follows through the processes by which these observations are used for computing steam tables, he will find that the accuracy is ample for any commercial steam-table work.

[1] Research Fellow, Harvard University.

Report on Progress in Steam Research at the Massachusetts Institute of Technology

BY FREDERICK G. KEYES,[1] CAMBRIDGE, MASS.

SINCE a year ago we have had considerable grief with our apparatus. Mr. Orrok has referred to the fact that the nickel bomb we were using developed a very slight flaw which was opening up under pressure. However, through the kindness and coöperation of Messrs. H. T. Cole and H. G. Fales of the International Nickel Company a piece of nickel especially worked was secured, which proved finally to be tight. All of our experience at the laboratory previously has been with steel, nickel steel, and other steel alloys. Pure nickel has properties which make it difficult to effect a reliable closure.

The last three months we have been working out methods of getting water into the apparatus. That would seem to be a comparatively simple task, but the capacity of the nickel bomb is some 230 cubic centimeters. We attempted to distill into the container a suitable quantity of water for experimental conditions, but it turned out to be a time-consuming job, and it was finally decided to pour it in. We had to work out a special method of pouring since the water must be gas-free and pure.

Suppose that we consider a diagram (Fig. 6) in which the pressure is plotted against volume. If the vapor is compressed, a point will

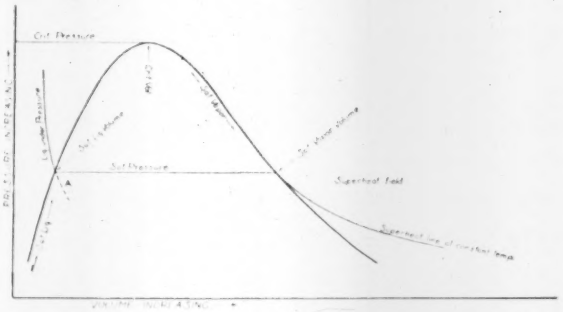

FIG. 6 VAPOR DIAGRAM

finally be reached where the vapor is just ready to collapse, called the saturation vapor volume, and thereafter the pressure will remain constant until all the vapor has disappeared and the liquid phase will be compressed. This process can be carried out at higher and higher temperatures until the critical temperature is exceeded. The first portion or field of the superheat is thus explored and the saturated specific volumes measured, as well as the saturation pressures, the saturated liquid volumes, and the compressibility of the liquid.

It is intended to cover the region above the steam dome up to at least 400 deg. cent. or about 750 deg. fahr. The diagram represents in principle how our apparatus works. Once the bomb is loaded, it is possible to bring the steam into the vapor phase, compress it continually, finally compressing liquid water. The procedure can be reversed and with varying masses of water until we are satisfied that reliable and accurate values have been obtained.

It is interesting to note that in passing from the compressed liquid back in the direction of the vapor phase, the vapor phase does not always form promptly at the saturated liquid volume. The retardation in vapor-phase formation permits one to stretch out the liquid as indicated by the dotted line at A. A number of atmospheres tension can in fact be exerted for a considerable time before the vapor phase forms and equilibrium occurs.

Fig. 7 is presented merely to give a purely diagrammatic representation of what the apparatus consists. A is the bomb containing pure water. It would be convenient to confine it with mercury, but that is impossible because the mercury-vapor pressure amounts to a great many atmospheres at high temperatures and it would be impossible to correct for its partial pressure accurately. The water of the bomb is connected by water through the nickel capillary tube E and leads to the tube B. The black portion represents mercury which extends up to a gage G. On the other side is a piston C, and the scale D is supposed to indicate displacement of that piston,

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account of which is taken accurately. To start out with, it is necessary to know the compressibility of mercury. The portion of water above the mercury in B is always invariably at 30 deg. cent. The temperature of the water in the capillary where it emerges from the hot-bath temperatures must be known accurately, and there is a a water-cooled condenser surrounding the capillary and thermocouples provided to record the actual temperatures. The corrections can be made fairly accurately. At 30 deg. we have compressibilities that seem to be reproducible within one part of a thousand. That is far greater accuracy than is needed for actual work, but it is interesting to know that the apparatus gives reprodicible results with this accuracy.

From the bomb to the point where the mercury-water tube screws into the steel apparatus, the metal is 99 per cent pure nickel.

Fig. 8 shows the volume-measuring piston. It is a special screw driven by a nut, the nut being provided with four handles. The nut, which has thrust bearings made by the Hyatt Roller Bearing

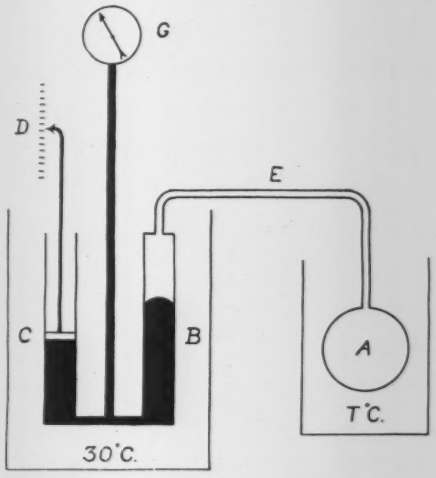

FIG. 7 DIAGRAMMATIC REPRESENTATION OF APPARATUS

Company, is divided on the lower edge into 100 divisions, so one can estimate one-thousandth of a turn. The estimated volume change corresponding to 0.001 turn is 0.00002 cu. in. The piston cylinder contains mercury. The mercury makes contact with the water, which in turn connects by means of the capillary to the nickel bomb. The insulated joint is evident back of the cylinder, connection with which is made to the gage by means of oil. The volume-measuring device is calibrated by measuring the mercury squeezed out when the screw is advanced through each five turns.

Fig. 9 represents the water-distilling apparatus. This was not a very simple job, but has finally been made satisfactory. The problem arose of discovering the best manner of distilling the water for purification. It is difficult to transfer large amounts of water through the vapor phase where time is to be conserved. Since it is necessary to seal the water from the air by means of mercury traps, it is important to so arrange the apparatus that mercury will not be carried over to the loading flask during the transfer of the liquid water through the vapor phase. A is a tube holding 250 cu. cm. of water, provided with a capillary where it can be sealed with a blowpipe. Below this is a ground joint. E is a device adopted for testing air, and is somewhat similar to the one used by the Bureau of Standards in the case of ammonia. To find out how much air is in a given amount of vapor, the water is condensed out and the remaining air pushed into the capillary and measured. The water loaded in the last time is surely as free as one part in five hundred thousand.

B represents the two vessels for distilling the water back and forth in as good a vacuum as possible. One bulb is placed in cracked ice and a bucket of water at 25 deg. is placed around the other bulb. The distillation must be repeated many times with frequent pumping and is tedious. It takes about a week to free sufficiently a quart of water of the air it contains.

Fig. 10 shows how the water is transferred into the bomb of the apparatus. The exact total weight of water which is in the apparatus is required. The apparatus to accomplish the transfer of the water

without contact with the air to the nickel bomb is represented by *F*, *B*, *D*, and *E*. *A* is the glass container represented by *A* in Fig. 11 but which has been sealed from the distillation system. At *D* is a small plug of glass on the side of the tube into which *A* is set by means of the greased ground-glass joint. Through *C* all air can

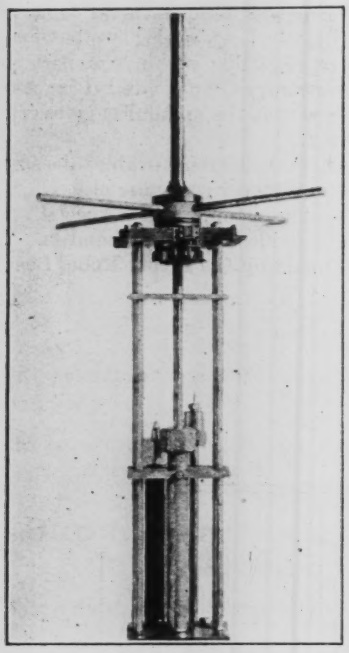

FIG. 8 VOLUME-MEASURING PISTON

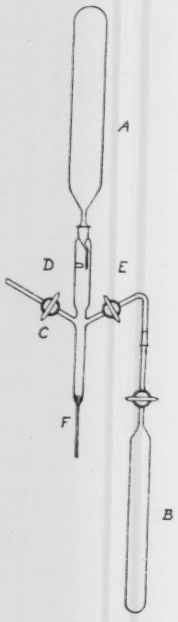

FIG. 10 SHOWING HOW WATER IS TRANSFERRED INTO THE BOMB OF THE APPARATUS

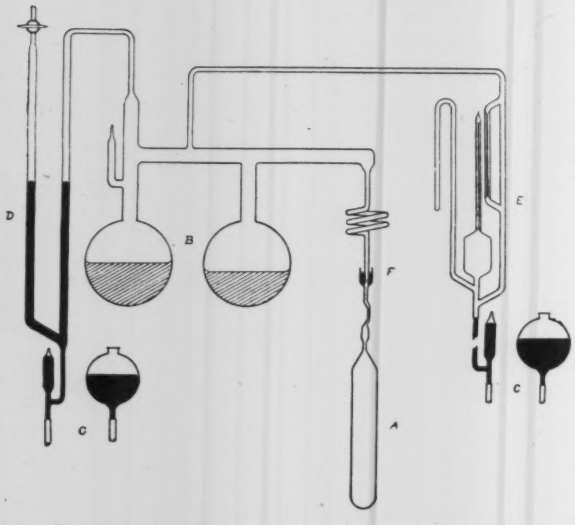

FIG. 9 DIAGRAMMATIC REPRESENTATION OF THE WATER-DISTILLING APPARATUS

be removed from the entire apparatus, *F* is the capillary coming down to the connecting block. Of course *A* contains somewhat more water than required. When the air has been pumped out, *A* is rotated in the ground joint and the tip snaps off by bringing up against the projection in the tube at *D*. After the water has run in, *E* is opened and the excess water run into *B*. Adjustment of the water is made with the volume-measuring piston where needed. *B* is weighed finally and by the difference between the weight of water in *A* and *B*, the weight of water in the bomb is ascertained. It is evident that the transfer has been made to the measuring apparatus without contact with the air. The device has worked very satisfactorily.

There is one comment that might be added. Evidently it is desirable to start with a large quantity of water. As the measurements progress, it will be desirable to take out some of the water. This can be done with the same apparatus by replacing *B*, *E*, and *D* and pumping out as before. The stop cock *F* is opened after closing *C* and by means of the volume piston, water is squeezed over into *B* and weighed. Progressing in this way, it is possible to cover the whole region to be measured with an initial loading of water.

The measurements to ascertain the compressibility of the water at 30 deg. cent. are about completed. These measurements are fundamental and much time has been spent to have no doubt concerning the accuracy of the reference data. Measurements are now being made of the expansion of the liquid phase to 160 deg. cent., and vapor-pressure measurements will start at this temperature. From now on, if no unforeseen circumstance interferes, data will accumulate steadily. When the next report is made, it is hoped that the whole field will have been measured. The final checking and correlation of the data will of course be a further part of the problem. Nevertheless the worst of the difficulties have been surmounted and a year from this time should see the investigation drawing to a conclusion.

Report on Progress in Steam Research at the Bureau of Standards[1]

BY NATHAN S. OSBORNE[2] AND H. F. STIMSON,[3] WASHINGTON D. C.

THE Cambridge Conference of June, 1921, recommended that series of measurements of two properties of steam be undertaken by the Bureau of Standards. One of these properties was the specific heat of the saturated liquid and the other the specific heat of the superheated vapor. At first these two series of measurements appeared to present two distinct problems, each requiring the development of separate calorimetric equipment, and a close connection between them was not at once recognized. The measurements on the liquid were selected as the more appropriate to be started when the completion of work then in progress should furnish opportunity. Attention was therefore centered on the saturation measurements, although the superheat measurements were kept in mind for future consideration.

A preliminary study of the experimental problem showed that equipment could be developed which would be suitable not only for measurements of the heat capacity of the liquid but also for determining other equally important properties of the saturated fluid. The entire group of determinations which would thus be provided for include the heat content, entropy, and specific heat of saturated liquid and vapor, the vapor pressure, and, within certain limitations, the specific volumes at saturation. Further study has indicated that the heat content of the superheated vapor may also be measured directly by use of virtually the same equipment.

Plans for experimental work and the design of apparatus have been guided by these possibilities for a systematic study of the behavior of steam, instead of restricting these plans to measurement of the specific heat of water alone.

This work is having the benefit not only of the existing facilities of the Bureau of Standards, but also of substantial support in the matter of materials, shop work, and scientific staff. It would be quite appropriate for this research to be supported entirely as a measure of public welfare. The fact that the Bureau has found it possible thus far to meet only about two-thirds the actual expense carries the advantage of that closer contact with the engineering profession which results from sharing with The American Society of Mechanical Engineers the privilege of providing the means for carrying on this important work.

The apparatus which is being prepared consists essentially of a calorimeter or heat-measuring instrument. This instrument will provide a place where a sample of water may be sufficiently isolated from other bodies to enable its amount, state, and exchange of energy to be accounted for. The sample may be made to pass through a chosen, accurately determined change of state while the accompanying gain or loss of heat is likewise accurately determined. The design of the apparatus provides for several such experimental

[1] Communicated by the Director of the Bureau of Standards.
[2] Physicist, U. S. Bureau of Standards.
[3] U. S. Bureau of Standards.

processes, selected for their physical simplicity and for their fitness and sufficiency to exhibit the thermal behavior of the fluid.

The main features of the apparatus and of the method have been described elsewhere.[1] Fig. 11 shows the design as brought up to date. It may be noted that some changes have been made in the tentative design of a year ago. These changes are partly the result of closer study of the details of assembling and partly the provision for additional experiments, but mostly the development of further details.

The range for which the experiments are being planned is from 32 to 575 deg. fahr. and to 1300 lb. per sq. in. Obviously it is not easy to obtain materials to build the various parts with assurance that they will serve continuously and reliably in contact with pure water under these rather severe conditions. The selection and acquiring of suitable materials have been important items in the recent progress. Pure silver has been adopted for resisting the action of hot water, and is used for construction where its mechanical and thermal properties permit. Alloys of silver, gold, and metals of the platinum group have been required in places where greater strength, hardness, or resistance to flow of heat was needed.

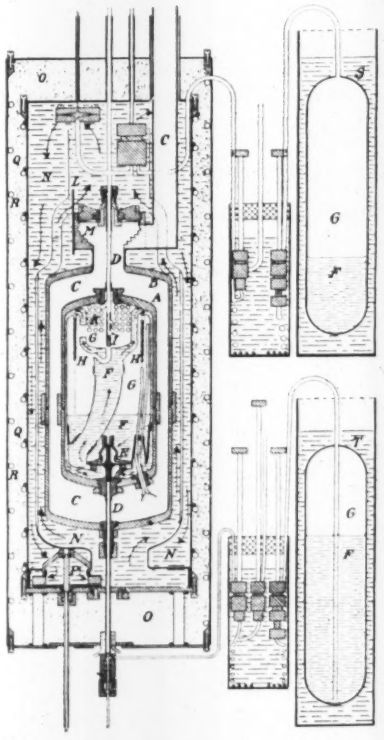

FIG. 11 SECTIONAL VIEW OF CALORIMETER

(*A*, calorimeter shell, copper-nickel alloy, silver-plated, 3 in. by 6 in.; *B*, envelope shell, copper-nickel alloy, 4 in. by 9 in.; *C*, vacuum space; *D*, outlet tubes, silver-palladium alloys; *E*, circulating pump; runs on iridium-alloy ball bearings; *F*, liquid; *G*, vapor; *H*, electric heater; *I*, vapor outlet and throttle; *K*, reheat tube, silver; *L*, receptacle for resistance thermometers, copper; *M*, receptacle for thermocouple reference junctions, copper; *N*, circulating liquid for thermal control; *O*, heat insulation; *P*, circulating pump; *Q*, heating and refrigerating coils; *R*, water cooling; *S*, reservoir for condensing vapor, silver; *T*, liquid reservoir, silver.)

Special problems in working these metals have been solved, and construction is proceeding well. The work of building this instrument with its delicate parts and essential sturdiness is very exacting and only the finest workmanship will suffice. Two instrument makers are now on this job, one having been already with it for about two years.

The construction of the central unit of the instrument where most of the extremely fine work occurs is now nearly completed. The surrounding parts, which are for controlling the experimental conditions and handling the samples of water, will be the next to build. Six shells of pure silver for water reservoirs and condensers have been obtained.

Another example of the kind of special problems in refined construction is the perfecting of a design for suitable shut-off valves for the connecting lines. Absolute tightness and reliability of operation are essential, and tests of models have shown the way to attain these characteristics. Fine workmanship will be needed here also.

The simple throttling device which has been developed to permit extension of the measurements to include the superheated vapor consists of a closely fitting threaded metal plug at the entrance to the vapor outflow tube. The throttling occurs as leakage past this thread, and the degree of throttling or drop in pressure may be adjusted by advancing or withdrawing this plug. After passing the throttle where the vapor is cooled it is next reheated to bring it back to the prevailing saturation temperature within the calorimeter by leading it through a coil of tube bathed with saturated vapor before it passes out of the calorimeter system.

[1] MECHANICAL ENGINEERING, vol. 46, no. 2, Feb., 1924, pp. 81 and 88; *Jour. Op. Soc. Am. & R. S. I.*, vol. 8, no. 4, Apr., 1924, p. 519; MECHANICAL ENGINEERING, vol. 46, no. 11a, Nov., 1924, p. 808.

The program of experimental work consists of:

1 A series of experiments to determine the specific heat and heat content of the saturated liquid. After making a change in connections there will next be made:

2 A series of experiments to determine the properties of the saturated vapor, including the latent heat of vaporization, the specific heat, entropy, vapor pressure, and specific volume

3 A series of experiments to determine the heat content of the superheated vapor.

It is very evident that disconnected measurements of the foregoing list of properties, each requiring the preparation of separate equipment, would take years to complete. It has not been unusual in the past for the determination of a single property of steam to occupy a group of experimenters for several years.

The present program, while it provides for the determination of an extended series of properties of steam, is arranged to take up the experiments in the order of least experimental difficulty and greatest promise of success. The time when observations can be started is now in sight. The completion of the first item will provide the data which the program of the steam table conference had assigned to the Bureau of Standards. In so far as preparations for the measurements of the specific heat of water are concerned, these are in advance of actual prospects at the time of the Cambridge conference. At the same time the possibilities of securing a greater return in new steam data have been developed far beyond our first expectations. Previous experience in a number of analogous calorimetric investigations has shown that the most expeditious way to attain the desired result involves thorough preparation. To the extent that obstacles can be anticipated and either avoided or overcome in the preliminary work, the measurements are spared puzzling discrepancies which require further experiments to interpret and evaluate. In making these preparations we have the advantage not only of the lessons to be learned from others but also of the advances which have been made in laboratory arts and of previous experience.

Progress Report on the Joule-Thomson Effect

BY HARVEY N. DAVIS,[1] CAMBRIDGE, MASS.

THIS, like Dr. Kleinschmidt's, is merely a progress report, but on the theoretical rather than the experimental side. A year ago we reported that the data then in hand had yielded constant total-heat lines and specific-heat ratios over our range of pressures and temperatures. These, with the Knoblauch observations of C_p had given a tentative C_{p0} curve and corresponding values for k. During the past year we have repeated this work giving increased attention to detail at various places in the calculations where the previous trial had shown this to be desirable. The results do not differ greatly from those reported a year ago.

We have also attempted to compute specific volumes and entropies, and at the same time to test out the formulation method of Callendar, Goodenough, and Heck. It will be remembered that all three of these authorities assume an equation of state for superheated steam of the form

$$p(v - b) = RT - X \quad \text{[I]}$$

where b is a co-volume term (assumed equal to zero by Heck), and X is a correction term expressed for convenience as a function of p and T. The chief differences between the three formulations lie in the forms assumed for the term X. Callendar used an extremely simple and convenient X, but this very simplicity apparently makes it impossible to fit his equations to our experimental data. With the more complicated X used by Goodenough and by Heck, Equation [I], when solved for v, becomes

$$v = b + \frac{RT}{p} - \frac{E}{T^m} - \frac{Fp^s - 1}{T^n} \quad \text{[II]}$$

It follows that the Joule-Thomson coefficient μ must fit the equation

[1] Professor of Mechanical Engineering, Harvard University. Mem. A.S.M.E.

$$\mu c_p = -b + \frac{(m+1)E}{T^m} + \frac{(n+1)Fp^{s-1}}{T^n} \quad \text{[III]}$$

At zero pressure this becomes

$$\mu c_{p0} + b = \frac{(m+1)E}{T^m} \quad \text{[IV]}$$

and log $(\mu C_{p0} + b)$ must plot linearly against log T.

In testing these equations against our data, we first sought a value for b which would make such a logarithmic plot straight. It was at once evident that neither $b = 1$, as assumed on theoretical grounds by Callendar and by Goodenough, nor $b = 0$, as assumed for convenience by Heck, was satisfactory. In both cases the logarithmic plot showed more curvature than could be accounted for by any reasonable limit of error in the experimental data. On the other hand, $b = -6.37$ cc. per gram was found to work very well. A negative b of such large numerical magnitude is, of course, absurd from the standpoint of kinetic theory, and therefore any formulation of this general type that is consistent with our data will necessarily have lost much of its elegance. But if we are willing to regard a formulation as a purely empirical interpolation machine, there is no reason why we should not be content as far as this first test is concerned.

Turning to higher pressures, we have, from Equation [III],

$$\mu C_p - \mu C_{p0} = \frac{(n+1)Fp^{s-1}}{T^n} \quad \text{[V]}$$

That is, the difference between μC_p at any temperature and pressure, and μC_{p0} at the same temperature but at zero pressure, should be expressible in terms of a power of T times a power of p. Over most of our range this prediction is in excellent agreement with our data. Near saturation, however, deviations appear which are very much larger than the supposed limit of error of the data. At each constant pressure these deviations cease to be important at about the same superheat (about 45 deg. cent. or about 80 deg. fahr.). Along the saturation line itself the deviations are large (20 to 30 per cent of μc_p) and they steadily increase as one goes from lower to higher pressures.

This shows that another term should be added to Equation [III] above, making it

$$\mu C_p = -b + \frac{(m+1)E}{T^m} + \frac{(n+1)Fp^{s-1}}{T^n} + \delta \quad \text{[VI]}$$

δ being zero everywhere except in a strip about 45 deg. cent. wide along the saturation line. In this strip δ is a function of both p and T, and is most easily handled by double-entry tabulation.

Let us now retrace our steps. If we start with Equation [VI], regarding it merely as an empirical representation of the observed μC_p's, we can write the usual differential equation for v and integrate it, but we are not led directly back to Equation [II] above, even with an appropriate new term containing δ. We are led instead to

$$v = b + Tf(p) - \frac{E}{T^m} - \frac{Fp^{s-1}}{T^n} - T\int_T^\infty \frac{\delta}{T^2}\,dT \quad \text{[VII]}$$

the unknown function $f(p)$ taking the place of the ordinary constant of integration. If we *assume* that $f(p)$ is R/p, Equation [VII] turns into Equation [II] (except for the δ term). But are we justified in making this assumption?

The affirmative argument has an enticing plausibility. One form of it might run as follows: Let Equation [VII] be written in the form

$$\frac{v}{T} = \frac{b}{T} + f(p) - \frac{E}{T^{m+1}} - \frac{Fp^{s-1}}{T^{n+1}} - \int_T^\infty \frac{\delta}{T^2}\,dT \quad \text{[VIII]}$$

Now let T increase indefinitely at constant p. Obviously four of the five terms in the right-hand member approach zero, and we have

$$f(p) = \lim_{T \to \infty} \left(\frac{v}{T}\right)_{p\,\text{constant}} \quad \text{[IX]}$$

Now as T increases indefinitely, v also increases indefinitely, and presently the molecules will be so far apart on the average that both their size (the b term of van der Waals' equation) and their mutual attraction (the a/v^2 term of van der Waals' equation) will cease to be important. That is, at sufficiently large volumes "every gas is a perfect gas." But, with perfect gases (and, for that matter, with imperfect gases for which van der Waals' equation holds),

$$\lim_{T \to \infty} \left(\frac{v}{T}\right)_{p\,\text{constant}} = \frac{R}{p} \quad \text{Q. E. D.} \quad \text{[X]}$$

That this argument is entirely fallacious has been forcibly impressed on us by several considerations. In the first place, having evaluated the various constants in Equation [VI], having tabulated δ, and having evaluated the δ-integral in Equation [VII] by mechanical quadrature, we assumed that $f(p)$ was R/p, and checked Equation [VII] against some of the observed specific volumes of Knoblauch, Linde, and Klebe. The agreement was invariably bad.

We then turned to air, for which a considerable body of experimental data is available, and tested Equation [X] by plotting pv/RT against $1/T$ (or preferably against, say, $1/T^3$) at constant pressure. If Equation [X] is true, each such plot should extrapolate to 1 when $1/T$ approaches 0. At no one of the eight pressures examined was an extrapolation to 1 reasonable. On the contrary, we concluded from these plots that, for air, the true form of Equation [X] is

$$\lim_{T \to \infty} \left(\frac{v}{T}\right)_{p\,\text{constant}} = \frac{R}{p}(1 + cp) \quad \text{[XI]}$$

where c is a small constant. When we made a similar assumption for steam and evaluated c by means of any *one* of Knoblauch, Linde and Klebe's observed volumes, the agreement of Equation [VII] with *all* of their volumes that lay within our range became entirely satisfactory.

The fallacy in the kinetic argument outlined above lies in the fact that the effect of an increase in the average distance between molecules is, *at constant pressure*, entirely offset by the effect of a corresponding increase in their average velocity. The statement, "at infinite volume any gas is a perfect gas," is sometimes far from true.

We are thus led to the formulation

$$v = b + \frac{RT}{p}(1 + cp) - \frac{E}{T^m} - \frac{Fp^{s-1}}{T^n} - \int_T^\infty \frac{\delta}{T^2}\,dT \quad \text{[XII]}$$

and familiar thermodynamic processes lead from this to

$$h = h_0 + \int_{T_0}^{T} C_{p0}\,dT + bp - \frac{Ep}{T^m} - \frac{Fp^s}{sT^n} - \int_0^p \delta\,dp \quad \text{[XIII]}$$

$$n = n_0 + \int_{T_0}^{T} \frac{C_{p0}}{T}\,dT - R\log_e p - cRp - \frac{mEp}{(m+1)T^{m+1}} - \frac{nFp^s}{s(n+1)T^{n+1}} - \frac{1}{T}\int_0^p \delta\,dp + \int_0^p \int_T^\infty \frac{\delta}{T^2}\,dT\,dp \quad \text{[XIV]}$$

We are also led to the conclusion that no less complicated formulation of the Callendar-Goodenough-Heck type adequately represents our data. We have shown by trial that these equations are not impossible from the computer's standpoint, although the labor involved is considerable. Doubtless formulations of other types can be found which will give equally satisfactory representations of the experimental facts. It is highly desirable that some of these possible alternatives be investigated with the hope of finding a set of equations that are both more convenient, and more attractive from the point of view of the kinetic theory.

Conclusions. If we attempt to formulate the properties of superheated steam by any set of equations of the Callendar-Goodenough-Heck type,

(*a*) We must abandon the idea that the co-volume term b has any theoretical significance whatever

(*b*) We must use a correction function X (see Equation [I] above) containing at least three terms, one of which (the δ term above) is not of the Goodenough-Heck type; and

(*c*) We must modify the RT term commonly regarded as the fundamental term in the right-hand member of an equation of state (or, what amounts to the same thing, include in X a fourth term of still another type).

Symposium on Lubrication

Practical Method for Determining Friction Coefficients, Based on a Wide Range of High-Pressure-Bearing Practice—Determination of Critical Breakdown Pressure in Oil Films Formed in a Bearing—Graphical Analysis of Lubrication of a Partial Bearing

THE three papers on journal lubrication presented at the Annual Meeting of the A.S.M.E., New York, December 1 to 4, 1924, with A. Kingsbury presiding, form a broad and valuable symposium on the subject. These papers,[1] which are to be reprinted in the Transactions of the Society, are abstracted briefly below. Louis Illmer's[2] paper on High-Pressure-Bearing Research presented a synopsis of some research investigations into the laws of friction and deduced a practical method for determining friction coefficients as based upon a wide range of high-pressure-bearing practice. The paper was more particularly directed toward the intermediate field of friction that lies between perfect-film and dry metallic friction. While Mr. Illmer based his work mainly on empirical results of practical experience, Leonard Noel Linsley[3] in his paper entitled An Investigation of the Critical Bearing Pressures Causing Rupture in Lubricating-Oil Films, presented the results of carefully devised experiments to determine the critical or breakdown pressure in the oil films formed in a bearing, and the influence on this critical pressure of the admixture of definite amounts of oleic acid. H. A. S. Howarth,[4] in a Graphical Study of Journal Lubrication (Part II), followed neither the empirical methods of Mr. Illmer nor the experimental methods of Mr. Linsley, but based his investigation on the early hydrodynamical theory of lubrication of Osborne Reynolds and the later work of English mathematicians. Mr. Howarth's paper continued a study in a previous paper of the same name by extending his graphical analysis to the case of a partial bearing.

High-Pressure-Bearing Research[5]

TO LIFT a journal against a given unit bearing pressure and permit of fully establishing an oil film, it is necessary to run the rubbing surface above a certain critical velocity. For the more common grades of mineral engine oils the following relationship obtains:

$$P_c = 140\sqrt[3]{\frac{V}{T}}$$

where P_c is the critical pressure at or below which a perfect oil film may be maintained under a journal when running at a given rubbing velocity V, lb. per sq. in. of projected area; $T = t_1 - 60° =$ virtual temperature deg. fahr.; and $t_1 =$ temperature of the rubbing surface, which should be limited to about 200 deg. fahr.

For a rigid journal copiously supplied with oil, rotating at relatively high speeds, with $P < P_c$, the coefficient of friction is taken as independent of velocity and is given by the equation

$$\mu = \frac{2}{5\sqrt{PT}}, \text{ with } \mu_{\text{min.}} = \frac{2}{5\sqrt{P_cT}}$$

Above the critical pressure, when the surfaces are no longer separated by a perfect film of oil whose rubbing friction is largely determined by the viscosity of the oil, we have "boundary" or partial film lubrication. In such lubrication the breaking down of the oil film causes a gradual increase in friction, depending largely upon the ratio $P_{\text{av.}}/P_c$. Such important factors as the need for heavier grades of lubricants and the increasing effect of unevenness in the rubbing surfaces are said by the author to be brought into fair agreement with practice when the above equations are modified into the form:

$$\mu_{\text{exc.}} = \mu_{\text{min.}}\sqrt[4]{\frac{P_{\text{av.}}}{P_c}} = \frac{2}{5\sqrt{P_cT}}\sqrt[4]{\frac{P_{\text{av.}}}{P_c}}$$

where $\mu_{exc.}$ = coefficient of friction under conditions of partial oil-film lubrication as applied to a journal bearing flooded with suitable mineral oil; and $P_{\text{av.}}$ = average dead-load pressure on the rubbing surface when $P_{\text{av.}} > P_c$, lb. per sq. in. of projected area. This assumes $P_{\text{av.}}$ to remain reasonably constant and for peak loads that maximum unit pressure does not exceed $1^1/_2$ to $2P_{\text{av.}}$

The above relationship can be simplified approximately to

$$\mu_{\text{exc.}} = \frac{1}{100}\sqrt[4]{\frac{P_{\text{av.}}}{VT}}$$

From these equations it is seen that whereas with perfect lubrication μ decreases with increase of pressure, with imperfect lubrication, $\mu_{\text{exc.}}$ increases with increase in pressure. Temperature effects are similar in both cases.

If the bearing temperature t_1 is taken as equal to 120 deg. fahr., so that T can be replaced by a constant value, and if a "circumstance" constant C_1 and a bearing-type constant C_2 are introduced, the equation for $\mu_{\text{exc.}}$ becomes

$$\mu_{\text{exc.}} = \frac{C_1C_2}{250}\sqrt[4]{\frac{P_{\text{av.}}}{V}}$$

Table 1 gives appropriate values of C_1.

TABLE 1 VALUES OF CIRCUMSTANCE CONSTANT C_1

C_1	Lubrication	Workmanship	Attendance	Location
1	Oil bath or flooded	High-grade	First-Class	Clean and protected.
2	Oil, free drop (constant feed)	Good	Fairly good	Favorable (ordinary conditions)
4	Oil cup or grease (intermittent feed)	Fair	Poor	Exposed to dirt or grit or other unfavorable conditions

The bearing-type constant C_2 is introduced where bearings other than rotating journals are employed; and has the values given in Table 2.

TABLE 2 VALUES OF TYPE CONSTANT C_2

C_2	Type and Example of Bearing
1	Rotating journals, such as rigid bearings and crankpins
1	Oscillating journals, such as rigid wristpins and pintle blocks
2	Rotating journals lacking ample rigidity, such as eccentrics and the like
2	Rotating flat surfaces lubricated from center to circumference, such as annular step or pivot bearings, etc.
2–3	Sliding flat surfaces wiping over the guide ends, such as reciprocating crosshead shoes. Use 2 for relatively long guides and 3 for short guides
3–4	Sliding or wiping flat surfaces lubricated from the periphery or outer wiping edge, such as marine thrust bearings and worm gears
4–6	Long power-screw nuts and like wiping parts over which it is difficult to effect a uniform distribution of lubricant or load.

To obviate disastrous heating effects the rubbing velocity should be kept within reasonable limits, and the author recommends the following rule which will give a factor of safety with respect to the abrasion limit of 2 or 3:

$$Ht_h = \mu_{\text{exc.}}P_{\text{av.}}V = \frac{C_1C_2}{250} \times P_{\text{av.}}V\sqrt[4]{\frac{P_{\text{av.}}}{V}}$$

where t_h = temperature head of rubbing surface with respect to the cooling medium or atmosphere, deg. fahr. (Allowances: 40 to 60 deg. fahr. rise for heavy-duty bearings; 60 to 90 deg. fahr. rise for high-speed bearings), and H = specific radiating capacity per sq. in. of maintained projected area of bearing.

When rubbing velocity is quite low, the heating effects are apt to be negligible and extremely high unit pressures are possible. The ultimate load-carrying capacity of such slow-speed bearings must then be restricted in accordance with the abrasive pressure limits of the respective materials used; and approximate values for material constants P_n are as given in Table 3.

[1] Contributed by the Machine Shop Practice Division and the Special Research Committee on Lubrication.

[2] Devel. Engr., Brewer-Titchener Corpn., Cortland, N. Y. Mem. A.S.M.E.

[3] Lieutenant-Commander, U. S. N., U. S. S. *Wright*.

[4] Genl. Mgr., Ch. Engr., Kingsbury Mch. Wks., Philadelphia, Pa. Mem. A.S.M.E.

[5] Abstract of paper by Louis Illmer.

TABLE 3 VALUES OF MATERIAL CONSTANT P_n

Materials in Contact	P_n, lb. per sq. in.	Remarks
Hardened tool steel on lumen or phosphor bronze	10,000	The given values apply to rigid polished and accurately fitted rubbing surfaces.
0.50 C machine steel on lumen or phosphor bronze	8,000	When not worn to a fit or well lubricated, reduce values to about $^3/_4$ P_n.
Hardened tool steel on hardened tool steel (common grades)	7,000	
0.50 C machine steel or wrought iron on genuine hard babbitt	6,000	
Cast iron on cast iron (close grained or chilled)	4,500	
Case-hardened machine steel on case hardened machine steel	4,000	
0.30 C machine steel on cast iron (close grained	3,500	
0.40 C machine steel on soft common babbitt	3,000	
Soft machine steel on machine steel (not case-hardened.)	2,000	
Machine steel on lignum-vitae (water-lubricated)	1,500	

To allow for full or partially reversing loads, a further constant C_3 is introduced having the following values:

Value of C_3	Load Characteristics	Example of Bearing
1	Dead or steady load	Such as generator main bearings
1.5	Variable or peak load	Such as punch and shear crankpins
2	Reversing loads	Such as steam-engine wristpins

To find the allowable limit pressure for well-fitted slow-moving bearings without appreciable heating effects, with a factor of safety of 2 to 3, when $C_4 = 1$, the following formula is recommended:

Where $V = 1$ ft. per min.,

$$P_{\text{lim.}} = 0.6\, C_3 C_4 \frac{P_n}{\sqrt[3]{V_e^2}} \sqrt[3]{H}$$

where $P_{\text{lim.}}$ = limiting average dead-load pressure allowable under negligible heating effects, lb. per sq. in. of projected area.

C_3 = load constant as previously tabulated

C_4 = intermittency factor: for continuous service = 1; for intermittent service, $1^1/_2$ to 2 as noted below

P_n = material constant

V_e = equivalent rubbing velocity, ft. per min. For slow-moving oscillating loads this may be taken as inches of movement actually under load × (r.p.m. ÷ 6)

H = specific radiating capacity of bearing or rate of heat dissipation.

In machinery intended for intermittent use it is permissible to reduce the factor of safety to some extent, and the above values make allowance for this.

Regarding the effect of materials in rubbing contact, the author points out that the coefficient $\mu_{\text{exc.}}$ is taken independently of the material constant P_n. Accordingly any combination of materials working within their load-carrying capacities and worn to a smooth fit may be expected to work with substantially the same friction coefficient under otherwise similar conditions. The chief advantage afforded by bearing metals having a high material constant P_n lies in their greater heat offtake and load-carrying capacities rather than in any inherent anti-friction attributes. Rubbing surfaces which carry a high P_n value are apparently smoother and capable of running in closer rubbing contact, and therefore less likely to abrade with a rise of bearing temperature. The allowable temperature head t_h is also usually raised in a direct relation to the material constant P_n.

As a summary of his investigations the author offers a modified formula:

When $P_{\text{av.}} > P_c$,

$$\frac{P_{\text{max.}}}{m} \sqrt[3]{\left(\frac{V}{n}\right)^2} = P_{\text{av.}} \sqrt[3]{V_e^2} = \frac{0.6 C_4}{C_1 C_2} P_n \sqrt[3]{H} = C_0$$

where $P_{\text{av.}} = P_{\text{max.}}/m$ = average unit bearing pressure, lb. per sq. in. of projected area. For repeated peak loads, such as in punches and shears, the bearing pressure is best restricted to that portion of a full revolution which corresponds to the cutting period as taken for the entire thickness of the sheared plate

P_{max} = unit peak pressure on the bearing, lb. per sq. in. of projected area

m = ratio $P_{\text{max.}}/P_{\text{av.}}$, which in the case of punches and shears may roughly be taken at about 2

$V_e = V/n$ = equivalent velocity applying while the mean load $P_{\text{av.}}$ acts on the bearing, ft. per min.

n = actual rubbing velocity V divided by V_e, which in the case of punches and shears may be taken at 3 to 4, depending upon the length of time required to cut the plate relative to the period of one revolution of the journal. For dead or uniform load, $n = 1$.

An important advantage offered by this equation lies in the fact that the bearing constants used for various kinds of high-pressure practice can be readily compared with each other as shown in Table 5, which is based upon a normal radiation of $H = 5$.

TABLE 5 HIGH-PRESSURE-BEARING CONSTANTS

Average values in practice: $P_{\text{max.}}$ lb.	Average values in practice: V/n ft./min.	Type of bearing	Kind of machine	P_n (Table 3)	Circum. const. C_1	Type const. C_2	Interm. factor C_4	$P_{\text{av}} V_e^{1/3} = C_0$ by Eq.
850	10	Main roll	Sugar mach.	8000	2	1	1	4000
650	10	Main roll	Sugar mach.	6000	2	1	1	3000
220	50	Gear shaft	Sugar mach.	6000	2	1	1	3000
85	200	Hangers	Lineshaft	3000	1	1	1	3000
70	100	Hangers	Lineshaft	3000	2	1	1	1500
1800/5	38	Wristpin	Oil engine	8000	2	1	1	4000
10,000/2	2/4	Pintle blocks	Punches and shears	4500	4	1	3	3400
4400/2	40/3	Main bearing	Punches and shears	8000	2	1	3	12,000
2000/2	50/4	Main bearing	Punches and shears	3500	2	1	3	5200
3300/2	60/3	Crankpins	Punches and shears	8000	2	1	3	12,000
5300/2	40/4	Crankpins	Punches and shears	8000	2	1	3	12,000
240/2	125	Countershafts	Punches and shears	3000	3	1	3	3000
2700	9	Main roll	Bending roll	8000	2	1	3	12,000
2000	5	Pin bearing	Guide rollers	8000	4	1	3	6000
500/4	65	Pin bearing	Cam rollers	8000	4	1	1	2000
45	200	Collar bearing	Marine thrust	6000	1	4	1	*1500
55	400	Collar bearing	Marine thrust	6000	1	2	1	3000
1400	10/2	Thrust collar	High-pressure	8000	2	2	2	4000
850	10	Power screws	Bending rolls	8000	2	2	2	4000
60/4	650	C. H. shoe	Engine work	4500	2	2	1	1100
850/2	10/2.5	Slide blocks	Punches and shears	4500	4	3	3	1100

An Investigation of the Critical Bearing Pressures Causing Rupture in Lubricating-Oil Films[1]

MR. LINSLEY in the introduction to his experiments draws the same general conclusions that Mr. Illmer does. The coefficient of friction decreases with the pressure until a minimum is reached at the critical pressure when the oil film breaks down and imperfect lubrication begins, and this minimum friction is independent of the rubbing velocity. Sommerfeld[2] and Stribeck,[3] two German investigators, have connected the critical pressure with the thickness of the oil film by the formula

$$P = \frac{\mu N}{349{,}556.5} \left(\frac{d}{\Delta}\right)^2$$

where μ = viscosity in poises

P = pressure in lb. per sq. in. of projected area

N = revolutions per minute

Δ = thickness of oil film in inches

d = diameter of journal in inches.

The difficulty with this method of attack lies in measuring the thickness of the film. Mr. Linsley decided that the work of Prof. Herbert S. Moore[4] in measuring the breakdown pressure of the oil film was more promising. Professor Moore deduced the following formula, which is largely used in design:

$$P = 7.47 \sqrt{V}$$

[1] Abstract of paper by Leonard N. Linsley.

[2] *Zeitschrift fuer Mathematik und Physik*, 1904, p. 597.

[3] *Mitteilungen ueber Forschungsarbeiten*, Heft 7. 1903.

[4] *American Machinist*, vol. 26, September 10, 1903, p. 1281.

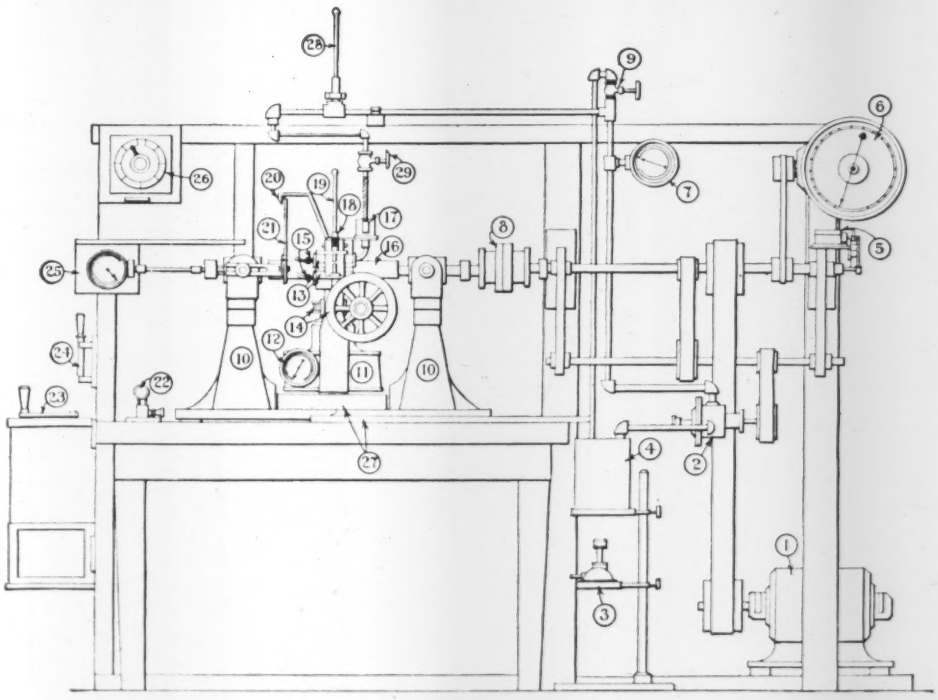

FIG. 1 APPARATUS FOR DETERMINING CRITICAL PRESSURES IN LUBRICATING OIL FILMS

1 Variable-speed motor
2 Rotary pump
3 Bunsen burner
4 Oil reservoir
5 Revolution counter
6 Centrifugal tachometer
7 Oil pressure gage
8 Flexible coupling
9 Oil pressure vent valve
10 Supporting bearings
11 Loadometer
12 Hydraulic pressure gage
13 Test bearing
14 Loading wheel and worm gear
15 Thermocouple inlets
16 Test journal
17 Sight-feed cups
18 Micrometer heads
19 Bearing thermometer
20 Deflection indicator
21 Deflection dial
22 Cut-out switch
23 Main speed controller
24 Line switch
25 Chronometric tachometer
26 Auxiliary speed controller
27 Oil drip pan and return
28 Oil inlet thermometer
29 Oil supply control valve

where P = breakdown pressure in lb. per sq. in. of projected area and V = rubbing velocity in ft. per min. (This formula is of a similar character to Mr. Illmer's formula $P_c = 140\sqrt[3]{V/T}$). Mr. Linsley undertook a check and extension of this formula.

The experimental apparatus finally decided upon is illustrated in Fig. 1, with various parts numbered. The test journal (16) was made of Sanderson's tool steel, described by the Crucible Steel Company of America as a straight-carbon tool steel containing 1 per cent carbon, and with phosphorus and sulphur content under 0.025 per cent. The journal was turned oversize, hardened, and then ground and lapped to exactly 2 in. diameter. The machine was belt driven by a closely controlled 3-hp., 1200-r.p.m., variable-speed, shunt motor. A Fast flexible coupling maintained alignment and reduced vibration. The test bearing consisted of a split bearing (13), the two halves of which were pressed together on the journal by means of a hydraulic loading device (11), as shown in Fig. 2. A suitable steel strap surrounded the jack and bearing so that the thrust of the jack was applied to both halves of the bearing. The total load applied by the jack was indicated by the pressure gage (12) which was graduated to read in pounds total load. The load was applied by rotating the worm gear by means of the hand-wheel (14). The bearing with the jack, loading mechanism, and supporting strap and other appendages, constituted a pendulum. The displacement of this pendulum through any angle φ indicated by the pointer (20) on the scale (21) was a measure of the friction involved. With this apparatus a table of coefficients of friction could be determined for a wide range of deflections and pressures from the formula

$$f = \frac{WR \sin \varphi}{Pr}$$

where W = weight of pendulum, R = radius from center of journal to the center of gravity of pendulum, r = radius of journal, P = total pressure on bearing, φ = angular displacement of the pendulum from the perpendicular, and f = coefficient of friction.

It should be noted that the radius R in the above expression is the same at all conditions of load, as the movement of the piston is very small, so small, indeed, that R is not disturbed under varying conditions of load.

The actual bearing surface was made in the form of a split sleeve which was bolted in the cast-iron holder. The bearing block which carried the bearing sleeve was split in the same manner as the sleeve and provided with spherical sections at the top and bottom that fitted into similar female sections attached to the strap at the top, and the head of the jack at the bottom.

The temperature of the bearing was determined by a mercurial thermometer (19) which was supported by a fiber bushing in a recess drilled into the bearing within an eighth of an inch of the bearing surface. Thermocouples made of copper and "advance" wire were fitted into recesses right at the entering and leaving edges of the actual bearing area so that the oil temperatures at both could be determined. The cold junctions of the thermocouples were immersed in melting ice in a vacuum bottle.

Vernier micrometers (18) were fitted to each half of bearing supporting blocks so that the vertical movement of the two halves of the bearing could be measured in relation to each other.

In applying the load, as the pressure increases, the oil film thins out until small points of contact occur. Before this point is reached the pendulum remains perfectly steady and the pointer (20) indicates a definite deflection which is a measure of the fluid friction; beyond this point, however, the pendulum grows increasingly unsteady until the critical point is reached, and the bearing grips the journal. When this occurs the pendulum is suddenly deflected through a large arc until its weight is sufficient to cause the driving

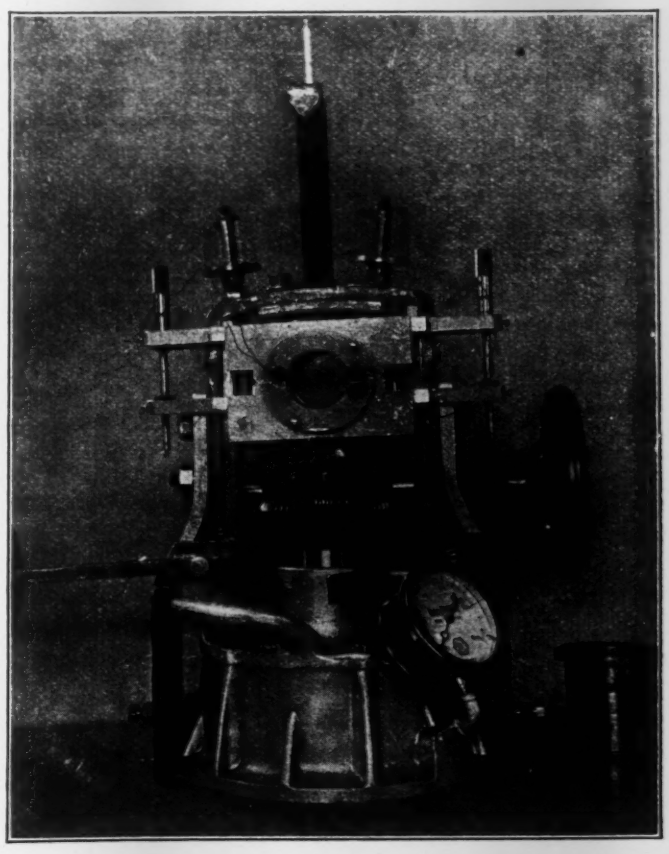

FIG. 2 HYDRAULIC LOADING DEVICE

belt, which is loosely fitted, to slip. The operator then opens the cut-out switch (22) and shuts down the machine. In getting the true breakdown pressure any irregular mechanical application of force is avoided by bringing the pressure up to a value just below the critical point and then allowing the increase of temperature to cause the viscosity to decrease until rupture occurs.

The characteristics of the oils used in tests are given in Table 6.

TABLE 6 CHARACTERISTICS OF OILS EMPLOYED

	A	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Gravity, deg. B.....	21.6	21.4	20.2	26.0	24.8	20.8	20.4
Specific gravity.....	0.9235	0.9247	0.9321	0.8974	0.9044	0.9284	0.9309
Flash point, deg. fahr...	340	330	385	375	410	355	550
Fire point, deg. fahr....	400	385	460	430	470	410	400
Saybolt viscosity at 100 deg. fahr.....	202	205	763	182	760	308	290

In tests with a cast-iron bearing it was found that the pressure causing rupture of the oil film was much greater than that calculated from Professor Moore's equation as given above; and that with each refitting of the bearing the pressure which was required to break the film became higher and even without a refitting, after the bearing seated itself better, the rupturing pressures grew appreciably higher. Lack of permanence in the fit of the bearing obscured real relationships and it was decided to continue with babbitt bearings.

TABLE 7 TEST WITH BABBITT BEARING USING OIL NO. 1

Speed, ft. per min.	Bearing pressure, lb. per sq. in. projected area	Temp. of bearing, deg. fahr.	Absolute viscosity, poises	Speed, ft. per min.	Bearing pressure, lb. per sq. in. projected area	Temp. of bearing, deg. fahr.	Absolute viscosity, poises
	Untreated				Untreated		
150	3650	107	0.34	480	3700	144	0.14
155	3000	123	0.22	500	4550	114	0.28
155	2900	132	0.18	525	4250	123	0.22
170	3400	115	0.27	530	3850	140	0.15
195	3750	108	0.33	540	3750	135	0.17
195	3300	119	0.24	555	3600	152	0.12
240	3300	137	0.16	570	4300	120	0.23
245	3850	114	0.28	570	3950	132	0.18
265	4050	112	0.30	575	3500	162	0.10
280	3700	123	0.22				
305	3350	148	0.13				
310	3250	162	0.10		Treated		
315	4050	119	0.24				
315	3750	125	0.21	155	2250	104	0.37
325	3550	140	0.15	175	2800	117	0.26
350	4350	113	0.29	225	2750	105	0.36
360	4250	113	0.29	240	3150	104	0.37
365	3450	144	0.14	275	2600	130	0.19
380	4050	120	0.23	350	3050	137	0.16
390	4200	118	0.25	350	2750	132	0.18
395	4100	118	0.25	450	3250	125	0.21
400	3900	130	0.19	450	2750	152	0.12
400	3650	140	0.15	500	3250	130	0.19
420	3500	162	0.10	500	2900	162	0.10
460	4150	119	0.24	510	3650	118	0.25
470	4450	115	0.27	550	3400	127	0.20
470	3850	137	0.16	550	3100	157	0.11

TABLE 8 TEST WITH BABBITT BEARING USING OIL NO. 5

Speed, ft. per min.	Bearing pressure lb. per sq. in. projected area	Temp. of bearing, deg. fahr.	Absolute viscosity, poises	Speed ft. per min.	Bearing pressure lb. per sq. in. projected area	Temp. of bearing, deg. fahr.	Absolute viscosity, poises
	Untreated				Untreated		
155	3500	121	0.32	495	4050	145	0.18
160	3750	120	0.33	500	4200	136	0.22
180	3250	130	0.26	530	4400	132	0.25
200	3100	148	0.17	530	3650	165	0.12
205	3600	129	0.27	535	3950	145	0.18
230	3150	154	0.15	550	3750	157	0.14
250	3650	133	0.24	555	3900	154	0.15
270	3850	130	0.26	565	3500	189	0.08
285	3200	175	0.10	575	4150	139	0.20
290	3450	154	0.15	575	4050	142	0.19
310	4200	124	0.30				
325	4050	129	0.27				
325	3700	142	0.19				
330	3300	175	0.19		Treated		
330	3950	133	0.24				
335	3500	160	0.13	200	2900	118	0.36
340	4200	126	0.29	215	2450	121	0.32
365	3750	145	0.18	260	3200	117	0.37
370	3900	136	0.22	275	2900	139	0.20
390	4200	127	0.28	335	2900	151	0.16
395	4350	127	0.28	375	3200	145	0.18
425	3750	151	0.16	400	2750	157	0.14
435	3850	148	0.17	410	3100	151	0.16
435	3650	157	0.14	460	3050	170	0.11
445	4350	129	0.27	475	3600	138	0.21
450	4050	138	0.21	490	3300	157	0.14
400	3450	170	0.11	500	2800	165	0.12
475	4400	129	0.27	535	2950	160	0.13
495	3600	165	0.12	555	3250	157	0.14

The general trend of results of the final trials, made with oils Nos. 1 and 5, are given in the curves of Figs. 3 and 4, and in Tables 7 and 8. The author states that it is too much to say that the curves represent what really happens, because it was recognized that the machine was mechanically deficient, the degree of fit not perfect, and the temperature observed was probably not that which really obtained in the film itself. But he believes that the data recorded do sensibly represent the magnitude of the breakdown pressures with this particular degree of fit.

Contrary to expectation the breakdown pressures obtained after the oils had been treated with the 2 per cent oleic acid were materially less than with the untreated oils. The breakdown point was not so sharply defined as with the straight mineral oils. The unstable period which indicated contact was much longer, and in consequence the actual critical points were very erratic. This apparent discordance was no doubt due in a large measure to the fact that the real temperature of the film was unknown, as in this case the contact friction caused the temperature to rise very rapidly and no doubt it was not properly registered by the method used.

The electrical method of determining the breakdown pressure was tried during the trials with the cast-iron bearing. The arrangement was similar to that used by Professor Moore. It consisted simply in connecting the bearing and journal in a circuit as shown in Fig. 5.

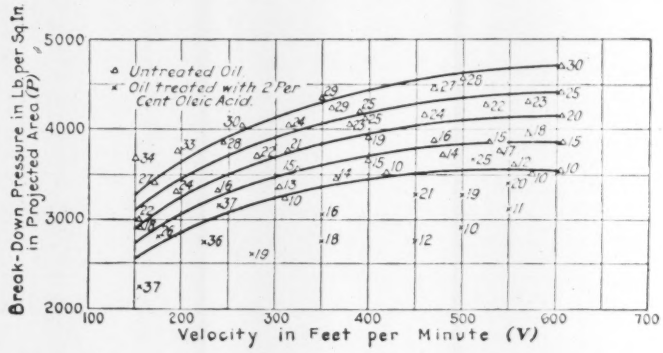

FIG. 3 BABBITT BEARING, 2.764 SQ. IN. PROJECTED AREA, OIL NO. 5, S = 308

(Numerals refer to absolute viscosity in poises. Circles refer to untreated oil. Crosses refer to oil treated with 2 per cent oleic acid.)

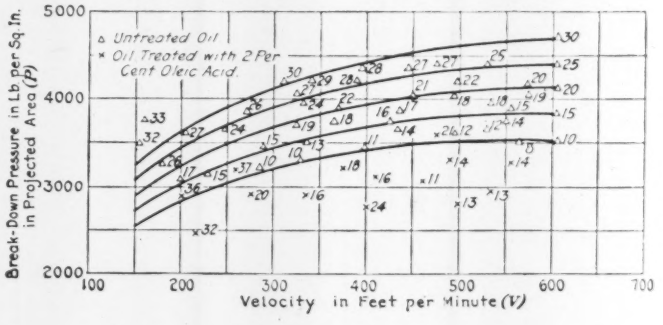

FIG. 4 BABBITT BEARING, 2.764 SQ. IN. PROJECTED AREA, OIL NO. 1, S = 205

(Numerals refer to absolute viscosity in poises. Circles refer to untreated oil. Crosses refer to oil treated with 2 per cent oleic acid.)

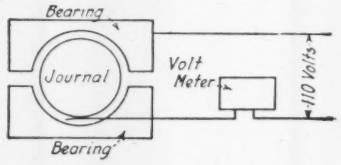

FIG. 5 DIAGRAM OF ELECTRICAL METHOD OF DETERMINING BREAKDOWN PRESSURE

The theory of this arrangement is, that as long as the film is maintained, the voltage, indicated on the voltmeter, will be zero, but when the film is ruptured metallic contact occurs and the voltmeter will indicate full-line voltage.

During the final trial a careful determination was made of the relative position of the two halves of the bearing by means of the micrometers. The average of all observations made while using oil No. 1 are shown in Fig. 6.

In view of the fact that the clearance in the bearing was maintained entirely by the pressure of the oil film, it is thought that the values determined are a fair approximation of the oil-film thickness. The method did not admit of closely measuring the movements of the bearing blocks near the critical point and consequently the magnitude of the oil film in this region could not be determined with great exactitude.

Conclusions. The most important fact brought out in this work is the astonishing intensity of pressure that the oil film will stand before being displaced. Even under the most adverse conditions of operation in the experimental work, it is seen that the actual breakdown pressures are several hundred times the values which have hitherto been accepted as possible. No indication of this has been recorded in the work of previous experiments with cylindrical bearings, so it is thought that this point can be claimed as an original contribution to the knowledge on the subject.

The relationship between breakdown pressure, speed and viscosity was not definitely established, but enough was accomplished in this direction to indicate that there is such a relationship and to develop its general character.

The actual breakdown pressures at which the film is completely dislodged and the bearing seizes the journal should not be considered as the critical pressures but rather the point at which metallic contact first makes itself manifest by the unstableness of the pendulum. This point should mark the limit, at least as far as economic loading of the bearing is concerned. It was deemed impractical if not impossible to determine this point exactly with the present apparatus, because the mechanism recording deflections of the pendulum was not delicate enough to indicate these first contacts with any degree of accuracy, so in order to get an unmistakable reference point the actual seizing pressure had to be the criterion. It should be noted, however, that the pressures at which unstableness was first noted were always near the seizing points.

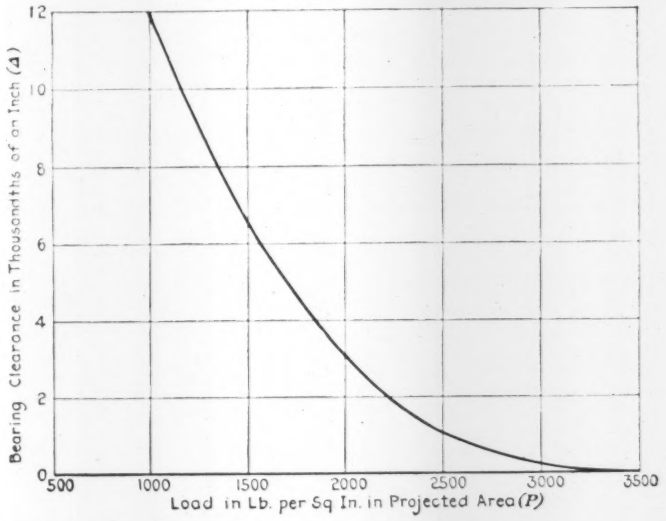

FIG. 6 BEARING CLEARANCE, OIL NO. 1, AVERAGE OF ALL OBSERVATIONS

The results with the oils treated with oleic acid indicate that the breakdown pressures with the oils so treated are less than with straight mineral oils. The experimental results in this direction were meager and it would not be safe to claim that this is invariably true without further confirmation. The influence from this evidence cannot be avoided, that oils having the same absolute viscosity but differing in chemical consistency do not have the same resistance to rupture and hence, from this point of view, differ in lubricating value.

A Graphical Study of Journal Lubrication (Part II)

MR. HOWARTH'S paper, of equal value and interest with those of Mr. Illmer and Mr. Linsley, does not lend itself readily to an abstract, and readers are referred to the volume of Transactions in which it will appear. Fundamental hydrodynamical equations form the basis of a graphical study of journal lubrication helpful to designers. Mr. Howarth studied journals running in full bearings and in partial bearings ranging from 60 deg. to 180 deg. with reference to oil viscosity, running clearance, load and speed in relation to each other, and in their influence on the friction, the position of the journal in the bearing, and the pressures within the lubricating film. The friction in partial bearings was not determined but will be published in a later paper.

Discussion of Papers Forming Symposium on Lubrication

MR. ILLMER'S paper on High-Pressure-Bearing Research was the first of the three to be read and discussed. M. D. Hersey[1] in presenting the paper criticized it on the ground that it represented a coördination of constants that in the author's opinion represented good practice, but was not based directly on either experiments or theory. In regard to the equation $\mu = \frac{2}{5\sqrt{PT}}$, Mr. Hersey thought this would apply at high speeds only, and that at low speeds rubbing velocity would have to be taken into account. He did not know where the author obtained justification for the equation $\mu_{exp.} = \mu_{min.} \sqrt[4]{\frac{P_{av.}}{P_e}}$, in which friction increases somewhat with the average pressure. He also emphasized the more or less empirical character of the equation $P_{min.} = 0.6\, C_3 C_4 \frac{P_n}{\sqrt[3]{V_e{}^2}} \sqrt[3]{H}$ and did not know where $\sqrt[3]{H}$ came from. Mr. Hersey pointed out, however, that the author's conclusions are fairly consistent with the results which were obtained in his own paper on Journal Bearing Friction (Trans. A.S.M.E., 1915) in which account was taken of viscosity, of permissible pressure, and of friction as the bearing heats up.

Prof. A. E. Flowers[2] stated that Batschinski in the 1900 Proceedings of the St. Petersburg Academy had shown that the absolute viscosity varied as the inverse cube of the absolute temperature.

In a written discussion of Mr. Linsley's paper on An Investigation of the Critical Bearing Pressures Causing Rupture in Lubricating Oil Films, presented by Carl E. Cummings,[3] H. F. Moore[4] said that the author had made reference to his (Professor Moore's) work performed at Cornell University in 1903, and had shown by his experiments that it was possible for an oil film to carry much higher loads without rupture than had been shown by the results of the Cornell experiments. The Cornell tests, however, had covered a very narrow range, and the formula deduced had been expressly given as a tentative formula in the absence of any other information available, but it gave results very markedly *on the safe side* of breakdown pressures.

While Professor Moore had been on the faculty of the University of Wisconsin, there had been made under his direction further tests on the breakdown strength of oil films using the electrical contact method to detect breakdown. The results of these tests had never been published. The bearings and journals used had been finished with a much greater degree of care than was the case in the Cornell tests, and the breakdown loads in the Wisconsin tests were about three times those found in the Cornell tests. It was Professor Moore's opinion that the breakdown strength of an oil film was very greatly affected by the roughness of journal and bearing. The author had pointed out that it was probable that the electrical contact method indicated not the actual breakdown of the film, but the thinning of the film to a point where small metal particles caused current to flow as they came between bearing and journal. This would seem to be a reasonable explanation. On the other hand, the location of the breakdown of the film at the point where well-marked "seizing" occurred, would seem to give too high a value, as the author had

[1] Chief Physicist, U. S. Bureau of Mines, Pittsburgh, Pa. Mem. A.S.M.E.
[2] Engineer in charge of Development, De Laval Separator Co., Poughkeepsie, N. Y. Mem. A.S.M.E.
[3] Texas Company.
[4] Research Professor of Engineering Materials, University of Illinois, Urbana, Ill. Mem. A.S.M.E.

pointed out. It seemed probable to Professor Moore that the attempt to locate the very first point of breakdown of film over a minute area would lead to results similar to those found in an attempt to locate the absolute elastic limit in metals; i.e., the value determined would depend largely on the sensitiveness of the apparatus used. It seemed to him that it might be worth while to develop some standard way of locating the breakdown point, even if the value thus determined was somewhat arbitrary.

M. D. Hersey pointed out that Sommerfeld's formula $P = \frac{\mu N}{349{,}556.5}\left(\frac{d}{\Delta}\right)^2$ applied only to clearances considered to be rigid, and in such rigid bearings only clearance and not actual film thickness had to be measured. Mr. Hersey, using an electrical method for measuring film thickness, had also shown that higher pressures were available in full bearings without breaking the film than in partial bearings. In further criticism of Mr. Linsley's paper, Mr. Hersey questioned the possibility of applying his results to rigid bearings, in which there was an unloaded half, while in Mr. Linsley's tests the bearing was not rigid, and both halves were loaded; this introduced serious differences in thicknesses of films present on either side of the journal. On the question of end leakage, Mr. Hersey said that a paper worthy of study on end leakage was to be found in the issues of the Monats-Blätter of the D.V.I. for May and June, 1914.

Prof. A. E. Flowers thought that the paper emphasized the immense importance of the fit of journal and bearing, and pointed to improvement in design by the selection of materials that would flow and not wear into a perfect concentric set of cylinders. As the friction coefficient was plotted, it went from a large value at nearly stationary conditions to a minimum, and then rose again. This minimum value had so far been considered the critical bearing pressure. Professor Flowers thought that the critical pressure spoken of by Mr. Linsley was more generally termed "seizing" pressure. B. H. Blood[1] thought "breakdown pressure" a better term than "seizing pressure" from a shop point of view.

C. H. Bierbaum[2] wished to know what the coefficient of friction was immediately preceding the breakdown pressure. He agreed with a comment already made that the term "seizing pressure" was better than that of breakdown pressure. Babbitt began to flow at between 1000 and 1500 lb. per sq. in. With pressures of over 4000 lb. tests were actually made under flowing pressures of the babbitt. Since there was a certain amount of spring and deflection of the babbitt, Mr. Bierbaum thought that the breakdown pressure must have been the pressure at which lubrication was completely excluded from the bearing. Regarding surface wear, he ventured the conjecture that the amount of surface wear that occurred in this test was so great that no machine designer would for one minute dare to take breakdown values as a permissible pressure.

Prof. E. O. Waters[3] corroborated the view that there was a great difference between the breakdown pressure as determined by Commander Linsley and the so-called critical pressures of Professor Moore and Professor Nicolson. In tests at the National Physical Laboratory, pressures even greater than those which were obtained by the Moore and Nicolson formulas gave no sign of seizing or of irregularity of readings, further emphasizing this difference.

N. E. Funk[4] thought that the paper indicated that greater protection was afforded by the use of more viscous oils, and did not agree with this. What happened in actual practice was that with the more viscous medium, the bearing temperature increased to the point where the viscosity decreased to the same value as the less viscous oil working at a lower temperature under the same bearing conditions. Therefore the resistance to seizure or to puncture of the oil film was actually the same with the oil of both high and low viscosity. Mr. Linsley's conclusion that contamination by oleic acid lessened resistance to puncture was in agreement with Mr. Funk's own experiments in which oil as it became old, became more acid and offered less resistance to seizure. Acid condition of the oil in practical operation also induced formation of sludges which clogged up passages and reduced the amount of lubricant that was available. Mr. Funk voiced a note of warning against the use of high pressures on the strength of the tremendous critical pressure indicated in the paper. These were obtained under perfect bearing-surface conditions. In actual bearing practice, however, there might be very serious local deviations from the mean; so that it would be wise to keep to large safety factors over mean pressures.

P. L. Irwin[1] said that the Westinghouse Research Department at East Pittsburgh were designing a machine in which much larger bearings would be tested. In line with Dr. Hersey's criticisms they intended to load the bearing solely from the bottom. They intended to load the bearings hydraulically, but in order to load solely from the bottom they were going to hang the pendulum on a hydraulic cylinder with trunnion-type bearings. Mr. Irwin asked whether Mr. Linsley's design, gripping from both top and bottom ends of the bearing, was used solely as a means of obtaining load in such a manner that the pendulum effect would not be retarded by any other apparatus or for measuring the film thickness by the micrometers.

H. B. Lewis[2] confirmed Mr. Funk's point of view in a test with two different oils, one about 620 Saybolt and the other about 200, finding that the viscosity under running conditions was the same for both.

W. F. Faragher[3] regretted that the effect of the function N/P had not been investigated. He had found that petroleum acid did not function in the detrimental fashion of oleic acid.

Prof. A. E. Flowers drew attention to the fact, brought out in Sommerfeld's classical paper, that starting friction was always the same no matter what viscosity of oil was used in the bearing. The minimum friction coefficients were also independent of the viscosity of the oil. Might it not be expected that at extremely high pressures difference of viscosity would be similarly without effect?

H. A. S. Howarth questioned Mr. Linsley's conclusions that he found the bearing and journal apparently about 80 per cent in contact. He thought that the author had dealt with bearings which did not quite fit the journal. With perfect fit, seizure would not occur up to infinite pressures. To load bearings heavily, surfaces must be well finished, and other conditions of lubrication correctly observed. He was interested to know what would have happened if the journal had been forced to run beyond the breakdown point. He thought that Mr. Linsley's method of applying pressures on both sides was indefensible theoretically, but that it allowed greater pressures to be applied, since the difficulty of shaft deflection was eliminated.

A. Schein[4] mentioned the case of an 8-in. diameter journal, ground and lapped to 0.002 in. with 80 per cent of the journal within 0.0001 in. With a load of 1600 lb. per sq. in. there was a deflection in the journal of 0.00075 in., but a proper thickness of babbitt having been selected, the babbitt conformed to the shaft deflection without undue stress. With a running velocity of close to 3400 ft. per min. perfect lubrication was attained and the journal was in operation for two years without wear.

Mr. Cummings closed the discussion on behalf of the author. To remove an erroneous impression he pointed out that the seizing pressures determined in Mr. Linsley's paper were not intended to represent the critical points of the oil film in the generally accepted sense of the word. The seizing pressures alone were determinable because of the character of the apparatus. In justifying the loading of the bearing on both sides, Mr. Cummings was of the opinion that Mr. Howarth had already met criticisms in this regard. In regard to the coefficient of friction preceding breakdown, Commander Linsley had data from which this could be figured. In answering queries regarding operation, Mr. Cummings said that difficulty was experienced with pressure decreasing in the hydraulic jacks during runs. He thought that Mr. Linsley's suggestions in regard to the extension of the work were very well worth consideration.

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[2] Vice-Pres., Cons. Engr., Lumen Bearing Co., Buffalo, N. Y. Mem. A.S.M.E.
[3] Asst. Prof. Machine Design, Yale University, Mem. A.S.M.E.
[4] Philadelphia Electric Co., Philadelphia, Pa. Mem. A.S.M.E.

[1] Research Engr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Jun. A.S.M.E.
[2] Brown & Sharpe Mfg. Co., Providence, R. I.
[3] Asst. Director, Mellon Institute, Pittsburgh, Pa.
[4] Sperry Gyroscope Co., Brooklyn, N. Y. Mem. A.S.M.E.

Safety in the Operation of Pulverized-Fuel Systems

Discussion of Papers Presented at the A.S.M.E. Annual Meeting, Including Particulars Regarding a Fire Recently Occurring in a Coal-Pulverizing Plant

AT THE Session on Mechanical Design for Safety held at the Annual Meeting of the A.S.M.E. on Wednesday morning, December 3, C. B. Auel[1] presiding, two papers, were presented, one by H. E. Newell[2] and Robert Palm[3] on the Hazards of Pulverized-Fuel Systems,[4] which discussed the principal features underlying proper installations, types of systems, driers, and safety requirements, and another on A Place for Safety, by Lewis A. DeBlois,[5] which was a general discussion of the accident-prevention movement, pointing out that production efficiency was increased by the adoption of safety features. Mr. DeBlois' paper appeared in the January issue of MECHANICAL ENGINEERING (p. 34).

In opening the discussion, Chairman Auel said that he was impressed with the present ramifications of the safety movement as compared with conditions a few years ago. It was then thought, he said, that the problem was simply one of mechanical design, but now it was recognized that the problem was much broader and extended into the field of health, and that he would be a bold man who would attempt to set the limitations to the safety movement. He addressed three questions to Mr. Palm who presented the first paper: namely, what fuels are best adapted to pulverized fuel systems? Why is pulverized fuel used? What are the hazards of leaky joints in such a system?

In answer to these questions, Mr. Palm pointed out that he was not a combustion engineer although he had seen many pulverized-fuel plants in operation. He considered the softer coals to be best adapted to pulverizing and said that there were used almost exclusively. He also pointed out that much of the mined coal could be used in pulverized plants which now goes on to waste piles. He mentioned the advantages of cleanliness, labor-saving operation, simplicity of firing, cheapness, etc. As to the third question, leaky joints, he said, constituted one of the worst hazards of the system. He pictured how, in plants with leaking joints, an explosion or flare-up would travel from one point of accumulated dust to another, causing dust clouds and consequent fire hazards. With no possibility of dust escaping, he said, and with clean methods of operation, the results of a minor explosion would be trivial. Tight joints, from the point of view of the safety engineer, he said, were of major importance, as were good housekeeping and common sense.

Col. Peter Junkersfeld[6] commended the work which Messrs. Newell, Ricketts, and Palm, as members of a sub-committee charged with revising regulations for the use of pulverized fuel, had done in their difficult task of making this revision. The regulations should be carefully considered by all interested, he said, because it represented accumulated and in many cases definite experience. Every reasonable safeguard against hazards of pulverized fuel might be provided, but would be futile if the operator did not maintain constant vigilance, particularly in the matters of good maintenance and good housekeeping. Running along day after day without demonstration of ever-present hazards, operators were very likely to consider requirements of cleanliness as unnecessary. To one who had not fully visualized the sources of hazard, he said, the slight accumulation of dust on structural members and in small piles might not appear serious. The ignition of a small pile of coal dust, or even some explosions in a pulverized-coal plant, were often, in themselves, not serious, particularly if proper vents and explosion relief were provided, but experience had shown that comparatively light or primary explosions sometimes caused a stirring up of dust and the creation of a dust cloud, which, in turn, caused a much heavier and more disastrous secondary explosion. In his experience, he said, he had found that good housekeeping paid in any power or industrial plant.

Colonel Junkersfeld also emphasized the need of air-tight gates and valves to driers. Temperature was not of serious importance, he said, as coal would not ignite, even at considerably elevated temperatures if the gates and valves were tight enough to exclude air.

John Van Brunt[1] could not concur with the authors that the so-called unit system was one of the safest. It was, he said, in so far as the mill itself was concerned. The mill did not pulverize to a larger proportion of coarse material, or to a smaller proportion of fine material. Much would depend on the coal. Eastern coal, such as Pocahontas, pulverized in a unit mill, would often result in a product of 85 per cent through 200 mesh. The control of the unit mill was difficult, he pointed out, as it was difficult to keep the proper proportion of air to coal when varying the capacity of the mill. This gave rise to mixtures difficult to ignite, to interruptions in the flame, and to flareback when the interruption ceased.

Henry W. Brooks[2] viewed as of great importance the success which had been obtained in burning high-ash fuels of all kinds, anthracite fines, anthracite culm, lignite and the lower-grade bituminous coals, and he felt that it was therefore exceedingly important that the advantages of the use of pulverized fuel should not be harmed through applications not conducive to maximum safety. He commented on a statement in the paper that compressed air, used with a water spray, might be safely used for blowing dust from motors or other inaccessible places. He pointed out that humidifying had not been quite effectual. He suggested the use of rock dust for the prevention of the explosion hazard in pulverized-fuel installations. He believed that in blowing down dust it would be advantageous to inject a stream of rock dust into the compressed-air system.

Mr. Brooks pointed out that one of the greatest hazards in pulverized coal plants existed during the construction period when men grew careless in permitting piles of dust to accumulate. If dust were allowed to accumulate, he said, it should be mixed with proper quantities of rock dust. He also felt that the breaker room should be rock-dusted.

Inasmuch as coal was an abrasive substance, he said, it was difficult to keep joints tight. Leaks should be repaired as soon as possible, and in the meantime the dust should not be allowed to accumulate.

Robert Palm said that the Committee had considered both blowing and vacuum systems of cleaning. The use of compressed air had been vetoed except where there was a little dust which could not be removed by other means. It was found, he said, that by humidifying the air, no dust cloud was raised.

In answer to a question by the chairman concerning records of explosions in pulverized-fuel plants, Mr. Brooks said that the Bureau of Mines kept no record of such explosions. He did not know of any which had resulted in any great loss of life in the past few years.

Mr. Brooks explained, in answer to a question by F. W. Dean[3] as to what was meant by hazard during construction, that he referred particularly to the period in which the plant was being started and the initial tests run.

Speaking on the subject of hazard in boiler plants not using pulverized fuel, Mr. Palm said that this hazard was not to be found in the boiler room but in the crusher room.

E. G. Bailey,[4] speaking from experiences with mine explosions,

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[1] Manager, Employee's Service Department, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. President, National Safety Council. Mem. A.S.M.E. Committee on Safety Codes.

[2] Engineer, National Board of Fire Underwriters, New York, N. Y.

[3] Consulting Engineer, New York, N. Y. Mem. A.S.M.E.

[4] See MECHANICAL ENGINEERING, Mid-November issue, vol. 46, 1924, no. 11a, p. 783.

[5] E. I. DuPont de Nemours & Co., Wilmington, Del. Past-President, National Safety Council.

[6] McClellan & Junkersfeld, Inc., 687 Trinity Pl., New York, N. Y. Mem. A.S.M.E.

[1] Ch. Engr., Combustion Engrg. Corp., 43 Broad St., New York, N. Y. Mem. A.S.M.E.

[2] Fuel Engr., Fuel Sect., U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa. Mem. A.S.M.E.

[3] Sec. Wheelock, Dean & Bogue, Inc., 141 Milk St., Boston, Mass. Mem. A.S.M.E.

[4] President, Bailey Meter Co., 2015 E. 46th St., Cleveland, Ohio. Mem. A.S.M.E.

emphasized the necessity for cleanliness, regardless of dusting or humidifying.

John Anderson[1] said that he had analyzed the dust found on the beams of a boiler room and had found it to be almost as good a fuel as the coal fired to the boiler. It was very fine, 300 mesh, and very dry. He said that in Milwaukee they had burned pulverized coal for six years in one plant and for four in another and had never had an explosion. He said that he had seen almost every condition in his plants and he was at a loss to know how to start a pulverized-fuel explosion.

H. G. Barnhurst[2] said that in twenty-six years' experience with pulverized fuel he had not seen or known of an explosion except once or twice where elevators had been opened in the presence of open torches. Pulverized fuel had been used in the cement industry for about thirty years. He had tried lighting a pile of pulverized coal. As long as the coal was on the floor in a pile, there was no danger, but if stirred and blown into the air there would be a puff of an explosion. Spontaneous combustion of the coal had given trouble when bucket conveyors had been used in coal elevators.

Lewis A. DeBlois said that in dusting buildings used in drying wood pulp he had used steam jets, which were cheaper than air, quite as effective, and did not raise a dust cloud.

The discussion of the paper by Mr. DeBlois was opened by Wm. Elmer[3] who spoke on certain safety features in connection with railroads. He said that everything should be done to prevent eye injuries to men on the road and in the shops. Men under his control were compelled to wear goggles when engaged in hazardous work and infractions of the rule were strictly punished. He also spoke of the safety of steel cars, and of the cost incident to their adoption by a railroad.

Robert Palm emphasized the fact that modern machinery could be designed so as to make accidents easily avoidable and guards unnecessary.

G. H. Myrick,[4] in a discussion contributed after the meeting, wrote that if the paper by Messrs. Newell and Palm had appeared a month or so earlier, he would have thought it good and one that should be kept in mind. However, after having experienced a fire of this sort on the day after the paper was presented, every thought brought forth was a command that must be lived up to. There was not anything so convincing as an actual experience, and it would be his effort to present some of the convincing facts that this fire had produced.

The fire occurred at about 6.00 p.m. on December 4. Work had stopped for the day, and the powdered-coal plant was being operated just as it had been for the past ten years.

Referring to Fig. 1, coal brought to the plant in freight cars was delivered to a crusher and separator and from there to a storage bunker. From this point the coal entered the pulverizing system, first going to a direct drier, which was about six feet from the pulverizer and in the same building. Two roller-type pulverizers with air separators then delivered the coal to dust collectors on top of a storage bin. A screw feed in the bottom of this bin delivered the coal to a suspension system which carried the pulverized coal to a forge shop.

A short time before a Kenyon pump had been installed at the bottom of this bin, which transmitted the coal several hundred feet to a boiler house where Fuller burning equipment was used. This system had proved satisfactory and had nothing to do with the fire.

Approximately one hour before the fire occurred, the air-suspension distributing system had been shut down and, according to statements of workmen, the drier also had been stopped a short time before the fire.

It was apparent from the breaks in the pipe leading from the one pulverizer that was in operation to the dust collector on top of the bin that the fire first took place in this part of the system. All of this pipe, the storage bin, and pulverizer showed the effect of excessive inside pressure, and the dust collector was broken open and the metal badly torn. It was apparent also that this first fire was not sufficient to cause all of the damage, and undoubtedly this smaller fire and resultant wind pressure disturbed the powdered coal lying around in the room close to it, and as this again took fire it had disturbed more loose powdered coal so that the burning was more or less of a continuous series of small explosions.

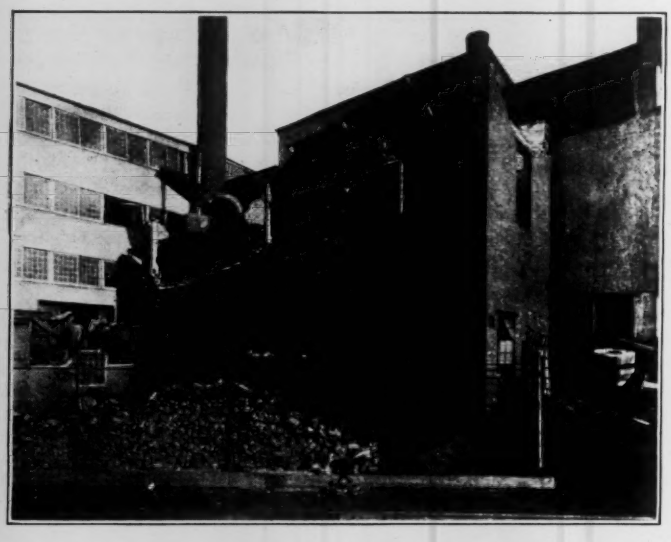

FIG. 1

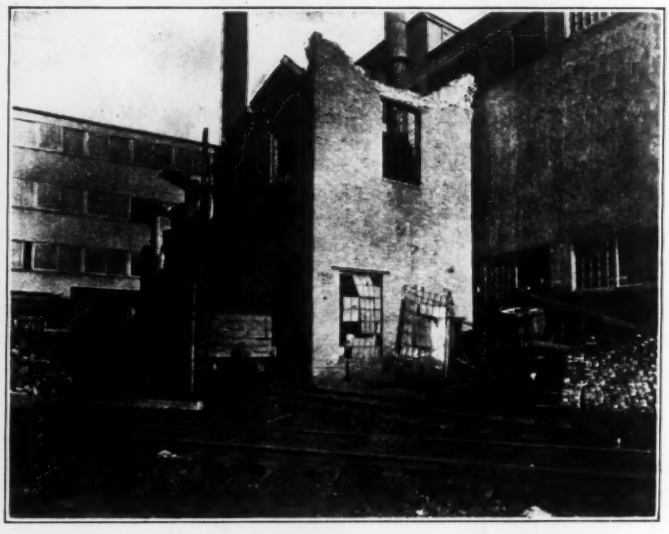

FIG. 2

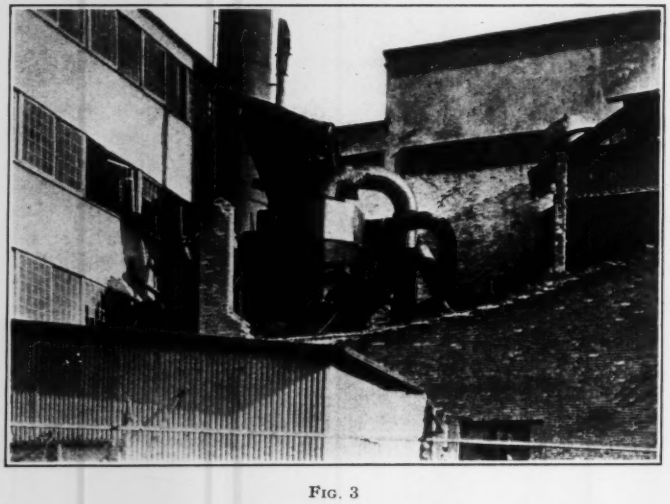

FIG. 3

FIGS. 1 TO 3 EFFECTS OF FIRE AND EXPLOSIONS IN A POWDERED-COAL PLANT

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[2] Advisory Engr., Fuller Engrg. Co., Fullerton, Pa. Mem. A.S.M.E.

[3] Supt. Middle Div., Penn. R. R., Altoona, Pa. Mem. A.S.M.E.

[4] Chief of Power and Combustion, Standard Steel Car Co. Butler, Pa.

There was no severe shock such as a dynamite explosion or a distilled-gas explosion, and men working in buildings near by were not sure at the time just what had happened. At the same time the flame propagation was not at all slow, as it would be noticed from Fig. 2 that at the top of the building a 13-in. wall was blown down, while the lower windows were not entirely blown out.

It was the general opinion, Mr. Myrick wrote, that this fire could have started from one of the following causes:

1 Dynamite had been found in the coal and a small piece might have been set off in the pulverizer.

2 The drier, having been shut down or possibly running slowly with too much heat, could have delivered coal too hot to the pulverizer.

3 The third likely cause was that the coal supply to the pulverizer might have been shut off, and the pulverizer, running with no coal, metal on metal, had heated up or given off sparks which had fired the gas in this transmission system.

The lesson to be learned, Mr. Myrick wrote, could be summarized as follows:

1 The buildings should be kept clean.

2 The apparatus should be segregated as much as possible. For instance, the forge shop adjacent to this plant, and where pulverized fuel was used, was just as badly covered with coal dust as the burnt building was, and had the fire advanced to the forge, there was no telling what damage it might have done.

3 All systems of air separation with dust collectors and storage tanks are subject to fire and explosion. And every precaution should be taken to minimize the hazards and also the effects of an explosion. In the direct unit system where the pulverized coal was delivered directly into the furnace, fire and explosion hazards were reduced to a minimum.

4 All buildings housing the pulverized-fuel equipment should be built so that a sudden excessive gas pressure on the inside would be relieved rather than push out the walls, and where possible, the collecting and storage system should not be housed at all.

5 Other precautions should of course be taken, such as good ventilation to take care of distilled gases. An explosion from this source was far more destructive than a fire from coal dust. All electrical apparatus should be given particular attention, and fire apparatus should be handy.

Proposed American Standards for Malleable and Cast-Iron Screwed Fittings

Report of Sectional Committee on the Standardization of Pipe Flanges and Fittings, Prof. Collins P. Bliss, Chairman

THE first reports to reach the sponsors of this Sectional Committee cover proposed standard dimensions for the following three complete series of fittings:

1 Malleable-Iron Screwed Fittings designed for 150 lb. Working Steam Pressure

2 Cast-Iron Screwed Fittings designed for 125 lb. Working Steam Pressure

3 Cast-Iron Screwed Fittings designed for 250 lb. Working Steam Pressure.

These reports were prepared by Sub-Committee No. 2 of which Stanley G. Flagg, Jr., is chairman. They were discussed in detail at a regular meeting of the Sectional Committee, and the letter ballot which followed indicated practically unanimous approval by the sixty-one (61) official representatives on the Sectional Committee. These reports were accordingly formally presented to the three sponsor bodies for approval and adoption and transmission to the American Engineering Standards Committee for approval and designation as Tentative American Standards.

Sectional Committee Organization

This Sectional Committee on the Standardization of Pipe Flanges and Fittings was organized during October, 1921, under the procedure of the American Engineering Standards Committee with the Committee of Manufacturers on Standardization of Fittings and Valves, the Heating and Piping Contractors National Association, and The American Society of Mechanical Engineers as joint sponsors. Its chairman is Prof. Collins P. Bliss and its secretary is Albert C. Taylor. So far four sub-committees have been organized to develop the details of the work assigned to the sectional committee: Sub-Committee No. 1 on Cast-Iron Flanges and Flanged Fittings, A. M. Houser, Chairman; Sub-Committee No. 2 on Screwed Fittings, S. G. Flagg, Jr., Chairman; Sub-Committee No. 3 on Steel Flanges, Prof. C. P. Bliss, Chairman; and Sub-Committee No. 4 on Materials, A. M. Houser, Chairman.

150-Lb. Malleable Screwed Fittings

Table 1 includes the dimensions for 90- and 45-deg. ells, tees, and crosses, straight sizes. The proposed standard for this type of fitting, however, covers:

a Reducing Ells, Tees and Crosses

b Street Ells, 90 and 45 deg., and Service Tees, both straight and reducing

c Pipe Caps

d 45-deg. Y's, straight and reducing

e Couplings

f Open-Pattern Return Bends

g Medium-Pattern Return Bends

h Close-Pattern Return Bends.

125-Lb. Cast-Iron Screwed Fittings

Table 2 contains the proposed standard dimensions for the 90- and 45-deg. ells, tees, and crosses with straight pattern. The present report, however, includes also proposed standard dimensions for reducing ells, tees, and crosses designed to withstand a steam pressure of 125 lb. per sq. in.

250-Lb. Cast-Iron Screwed Fittings

Table 3 records the proposed standard dimensions for the ells (90 and 45 deg.), tees, and crosses with straight pattern. The full report, however, includes also proposed standard dimensions for reducing ells, tees, and crosses designed to withstand a steam pressure of 250 lb. per sq. in.

TABLE 1 PROPOSED STANDARD MALLEABLE-IRON SCREWED FITTINGS
(150 Lb. Working Steam Pressure, Straight Pattern—All Dimensions in Inches)

Nominal pipe size	*A* Center to end, elbow, tee, and cross	*A*[1] Center to end, 45-deg. elbow	*Z* Length of thread, min.	*C* Tap clearance, elbow, tee, and cross	$\frac{OD\ pipe}{2}$	*Q* Width of band, min.	Inside Diameter min.	Inside Diameter max.[1]	*V* Metal thickness, min.	*O* Outside diameter of band, min.
1/8	0.69	0.68	0.25	0.2375	0.2025	0.200	0.405	0.435	0.090	0.693
1/4	0.81	0.73	0.32	0.2200	0.2700	0.215	0.540	0.584	0.095	0.844
3/8	0.95	0.80	0.36	0.2525	0.3375	0.230	0.675	0.719	0.100	1.015
1/2	1.12	0.88	0.43	0.2700	0.4200	0.249	0.840	0.897	0.105	1.197
3/4	1.31	0.98	0.50	0.2850	0.5250	0.273	1.050	1.107	0.120	1.458
1	1.50	1.12	0.58	0.2625	0.6575	0.302	1.315	1.385	0.134	1.771
1 1/4	1.75	1.29	0.67	0.2500	0.8300	0.341	1.660	1.730	0.145	2.153
1 1/2	1.94	1.43	0.70	0.2900	0.9500	0.368	1.900	1.970	0.155	2.427
2	2.25	1.68	0.75	0.3125	1.1875	0.422	2.375	2.445	0.173	2.963
2 1/2	2.70	1.95	0.92	0.3425	1.4375	0.478	2.875	2.975	0.210	3.589
3	3.08	2.17	0.98	0.3500	1.7500	0.548	3.500	3.600	0.231	4.285
3 1/2	3.42	2.39	1.03	0.3900	2.0000	0.604	4.000	4.100	0.248	4.843
4	3.79	2.61	1.08	0.4600	2.2500	0.661	4.500	4.600	0.265	5.401
5	4.50	3.05	1.18	0.5375	2.7815	0.780	5.563	5.663	0.300	6.583
6	5.13	3.46	1.28	0.5385	3.3125	0.900	6.625	6.725	0.336	7.767
8	..	..	1.47	....	4.3125	1.125	8.625	8.725	0.403	9.995
Special Sizes Made to Order										
4 1/2	4.13	2.83	1.13	0.5000	2.5000	0.717	5.000	5.100	0.281	5.955
7	..	..	1.43	....	3.8125	1.012	7.625	7.725	0.370	8.883

[1] Maximum diameter equals O.D. of pipe plus one depth of thread.

General Notes and Tolerances

1 Variations in tapping and dieing will be limited to one turn either way from standard size as determined by the working gages prescribed by the American Standard Pipe Threads.

2 It is recommended that all internal threads be countersunk a distance equal to one-half the pitch of the thread and at an angle of 60 deg. with the axis of the thread, and that all male threads be chamfered at an angle of 45 deg. both for the purpose of easier entrance in making a joint and for protection of the thread.

3 The length of threads specified in all tables is to be measured to include the countersink or chamfer.

4 The addition of ribs or lugs is not prohibited on any screwed fitting.

5 It is recognized that some variations are absolutely unavoidable in the making of patterns and castings. In order to define what may be considered a reasonable degree of accuracy in the center-to-end measurements of all screwed fittings, the following inspection limits are set up.

TABLE 2 PROPOSED STANDARD CAST-IRON SCREWED FITTINGS[1]
(125 Lb. Working Steam Pressure, Straight Pattern—All Dimensions in Inches)

Nominal pipe size	A Center to end, elbow, tee, and cross	A1 Center to end, 45-deg. elbow	Z Length of thread, min.	C Tap clearance, elbow, tee, and cross	Q OD pipe / 2	Q Width of band, min.	Inside diameter min.	Inside diameter max.[2]	V Metal thickness, min.	O Outside diameter of band, min.
1/8	0.69	0.68	0.25	0.237	0.203	0.31	0.405	0.435	0.100	0.75
1/4	0.81	0.73	0.32	0.220	0.270	0.38	0.540	0.584	0.110	0.93
3/8	0.95	0.80	0.36	0.252	0.338	0.44	0.675	0.719	0.120	1.12
1/2	1.12	0.88	0.43	0.270	0.420	0.50	0.840	0.897	0.130	1.34
3/4	1.31	0.98	0.50	0.285	0.525	0.56	1.050	1.107	0.155	1.63
1	1.50	1.12	0.58	0.262	0.658	0.62	1.315	1.385	0.170	1.95
1 1/4	1.75	1.29	0.67	0.250	0.830	0.69	1.660	1.730	0.185	2.39
1 1/2	1.94	1.43	0.70	0.290	0.950	0.75	1.900	1.970	0.200	2.68
2	2.25	1.68	0.75	0.312	1.188	0.84	2.375	2.445	0.220	3.28
2 1/2	2.70	1.95	0.92	0.343	1.437	0.94	2.875	2.975	0.240	3.86
3	3.08	2.17	0.98	0.350	1.750	1.00	3.500	3.600	0.260	4.62
3 1/2	3.42	2.39	1.03	0.390	2.000	1.06	4.000	4.100	0.280	5.20
4	3.79	2.61	1.08	0.460	2.250	1.12	4.500	4.600	0.310	5.79
5	4.50	3.05	1.18	0.539	2.781	1.18	5.563	5.663	0.380	7.05
6	5.13	3.46	1.28	0.538	3.312	1.28	6.625	6.725	0.430	8.28
8	6.56	4.28	1.47	0.778	4.312	1.47	8.625	8.725	0.550	10.63
10	8.08	5.16	1.68	1.025	5.375	1.68	10.750	10.850	0.690	13.12
12	9.50	5.97	1.88	1.245	6.375	1.88	12.750	12.850	0.800	15.47
14	10.40	..	2.00	1.400	7.000	2.00	14.000	14.100	0.880	16.94
16	11.82	..	2.20	1.620	8.000	2.20	16.000	16.100	1.000	19.30
Special Sizes Made to Order										
4 1/2	4.13	2.83	1.13	0.500	2.500	1.13	5.000	5.100	0.34	6.38
7	5.84	3.87	1.43	0.598	3.812	1.43	7.625	7.725	0.49	9.45
9	7.27	4.69	1.56	0.898	4.812	1.56	9.625	9.725	0.62	11.80
15	11.13	..	2.10	1.530	7.500	2.10	15.000	15.100	0.94	18.12

[1] Sizes 14 in. and larger are to be used with outside diameter of pipe of the same size.
[2] Maximum diameter equals outside diameter of pipe plus one depth of thread.

TABLE 3 PROPOSED STANDARD CAST-IRON SCREWED FITTINGS[1]
(250 Lb. Working Steam Pressure, Straight Pattern—All Dimensions in Inches)

Nominal pipe size	A Center to end, elbow tee, and cross	A1 Center to end, 45-deg. elbow	Z Length of thread, min.	C Tap clearance, elbow, tee, and cross	Q OD pipe / 2	Q Width of band, min.	Inside diameter min.	Inside diameter max.[2]	V Metal thickness, min.	O Outside diameter of band, min.
1/4	0.94	0.81	0.43	0.238	0.270	0.49	0.540	0.584	0.18	1.17
3/8	1.06	0.88	0.47	0.255	0.338	0.55	0.675	0.719	0.18	1.36
1/2	1.25	1.00	0.57	0.260	0.420	0.60	0.840	0.897	0.20	1.59
3/4	1.44	1.13	0.64	0.273	0.525	0.68	1.050	1.107	0.23	1.88
1	1.63	1.31	0.75	0.217	0.658	0.76	1.315	1.385	0.28	2.24
1 1/4	1.94	1.50	0.84	0.267	0.830	0.88	1.660	1.730	0.33	2.73
1 1/2	2.13	1.69	0.87	0.305	0.950	0.97	1.900	1.970	0.35	3.07
2	2.50	2.00	1.00	0.312	1.188	1.12	2.375	2.445	0.39	3.74
2 1/2	2.94	2.25	1.17	0.331	1.437	1.30	2.875	2.975	0.43	4.60
3	3.38	2.50	1.23	0.395	1.750	1.40	3.500	3.600	0.48	5.36
3 1/2	3.75	2.63	1.28	0.470	2.000	1.49	4.000	4.100	0.52	5.98
4	4.13	2.81	1.33	0.545	2.250	1.57	4.500	4.600	0.56	6.61
5	4.88	3.19	1.43	0.664	2.781	1.74	5.563	5.663	0.66	7.92
6	5.63	3.50	1.53	0.783	3.312	1.91	6.625	6.725	0.74	9.24
8	7.00	4.31	1.72	0.968	4.312	2.24	8.625	8.725	0.90	11.73
10	8.63	5.19	1.93	1.320	5.375	2.58	10.750	10.850	1.08	14.37
12	10.00	6.00	2.13	1.495	6.375	2.91	12.750	12.850	1.24	16.84
14	11.00	..	2.25	1.750	7.000	3.10	14.000	14.100	1.33	18.40
16	12.50	..	2.45	2.020	8.000	3.45	16.000	16.100	1.50	20.88
Special Sizes Made to Order										
4 1/2	4.50	2.94	1.38	0.620	2.500	1.65	5.000	5.100	0.61	7.23
7	6.38	3.88	1.68	0.883	3.812	2.07	7.625	7.725	0.81	10.50
9	7.75	4.69	1.81	1.128	4.812	2.40	9.625	9.725	0.98	12.98
15	11.75	..	2.35	1.900	7.500	3.28	15.00	15.10	1.41	19.64

[1] Sizes 14 in. and larger are to be used with outside diameter of pipe of the same size.
[2] Maximum diameter equals outside diameter of pipe plus one depth of thread.

Tolerances for Center-to-End Dimension—All Dimensions in Inches

Nominal pipe size	1/8	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2
Center to end ±	0.03	0.04	0.05	0.06	0.06	0.07	0.07	0.08
Nominal pipe size	2	2 1/2	3	3 1/2	4	4 1/2	5	6
Center to end ±	0.08	0.10	0.10	0.10	0.12	0.12	0.12	0.14
Nominal pipe size	7	8	9	10	12	14	15	16
Center to end ±	0.14	0.16	0.18	0.19	0.21	0.23	0.24	0.25

Comment Desired

Abstracts of these three reports are printed in MECHANICAL ENGINEERING as part of the precedure laid down by the Council of The American Society of Mechanical Engineers for the approval and adoption of standards by that Society. Those desiring to examine the full reports for the purpose of criticism and comment may secure galley proofs by addressing C. B. LePage, Assistant Secretary A.S.M.E. (Standards), 29 West 39th St., New York.

Plymetl consists of a core of laminated wood with galvanized steel faces cemented to it and is made by the Haskelite Manufacturing Co., of Chicago. In order to determine its value for street-car bodies, girders made of this material were subjected to tests at the Case School of Applied Science and at Northwester University. The girder tested was made of three-ply wood 5/16 in. thick and was reinforced with small shapes and strips of steel riveted to it. The rivets are inserted while hot but do not burn the wood. It was found that the composite material can be securely fastened to the steel frame by hot riveting and the original article gives the results of tests. Calculations are claimed to show that the Plymetl girder is much stiffer than a steel girder of the same weight. (*Automotive Industries*, vol. 51, no. 21, Nov. 20, 1924, p. 889.

Description of a bearing where the balls are located in the form of a spiral series, i.e., threadwise, between the housing and the sleeve, the arrangement of the balls in the cage being such that each ball runs on a different portion of the raceway. The capacity of the bearing to carry heavy loads is said to be increased due to the fact that a greater number of large balls can be disposed in spiral fashion along the length of the bearing that could be confined in a single or even double track. Thus, in a Spiro 2 1/4-in. lineshaft bearing there are 48 balls 7/16-in. diameter as against, say, 18 balls at the most in a single-track bearing of corresponding dimensions. Furthermore, in a Spiro bearing there are at least three of the balls always in a position to support the direct load as against one ball in a single-track bearing. It is also claimed that this bearing is automatically lubricated. (*Machinery* (Ldn.), vol. 25, no. 633, Nov. 13, 1924, pp. 210–213.)

A locomotive at present under construction at the works of Beyer, Peacock & Co., Ltd., Manchester, England, consists of a boiler-carrying vehicle and a turbine-driven condenser vehicle, the latter having three pairs of coupled and driving wheels. The drive from the main turbine to the driving wheels is performed by means of direct double helical gearing having three reductions, the ratio of the gearing being 1 to 25.22, the final drive from the last gear shaft to the driving axle being by means of a quill or hollow axle operating through links, giving a flexible connection to the driving wheels. Coupling rods are used for the drive of the intermediate and trailing coupled wheels. The main gearing is contained within a dustproof casing, slung to the main frames in such a manner as to allow for movement of the frames.

The main frames are placed outside the wheels with outside axle boxes and crank arms; a four-wheeled truck carries the trailing end of the vehicle.

The main turbine is of the axial-flow type giving an output of 2000 hp., and has a speed of 10,000 r.p.m. for an engine speed of 70 m.p.h., the driving wheels being 5 ft. 3 in. in diameter. Such a speed will of course be easily attainable, as owing to the complete absence of reciprocating parts the engine can be perfectly balanced. This turbine is fixed to the condenser body and flexibly connected to the main gearing by means of flexible couplings.

Reversing is effected by means of an idle shaft and gears operated from the driver's footplate by hand or oil gearing. (*Railway Gazette*, vol. 41, no. 24, Dec. 12, 1924, pp. 768–769.)

Classification of Engineering and Industrial Standards

By F. J. SCHLINK,[1] NEW YORK, N. Y.

INDUSTRIAL standardization is the setting up, publication, and use of units, constructional forms, designs, manufacturing methods, processes, or routines which are determined upon by engineering study and analysis as being best and most economical for their respective purposes, in place of diverse ones of varying or indefinite character and quality. By this planned uniformity of operation, process, or product, standardization brings about economy in material, labor, and administration.[2]

Standards are of several kinds:[3]

I—*Fundamental Units and Standards of Length, Mass, Time, Temperature, Etc.* The most fundamental type of standards is the basic weight and measure standards of the country, such as the standard yard and pound, the volt, the candlepower, etc. as defined by legal or other authority, and referred to fundamental or prototype standards carefully maintained in the vaults and laboratories of the Bureau of Standards at Washington. (See Circular 47 of the Bureau, "Units of Weight and Measure.")

EXAMPLE: A gallon is a unit of capacity equal to the volume of 231 cubic inches. It is used for the measurement of liquid commodities only.

These are not ordinarily considered as within the scope of industrial standardization, but they are of first importance in any standardization program.

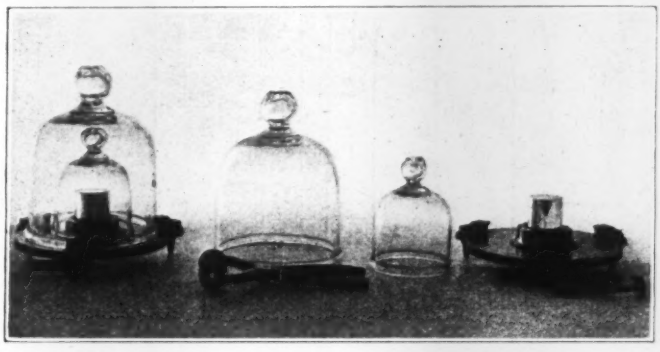


FIG. 1 A FUNDAMENTAL STANDARD OF MASS, THE UNITED STATES PROTOTYPE OF THE INTERNATIONAL STANDARD KILOGRAM

(The relation of the U. S. pound and the metric kilogramh as been established by act of Congress. Photograph by courtesy of the National Bureau of Standards.)

The determination and definition of these standards in such form that they can be reliably used and reproduced when needed, represent an enormous amount of work, of incalculable importance to industry, inasmuch as they permit the reproduction of standardized dimensions without the necessity of building and maintaining an actual model or sample. If the fundamental units of measure were not completely set up, both theoretically and practically, it would be necessary to record and perpetuate each manufacturing standard as a concrete constructed object or article, or a series of such articles, which would have to be copied by direct transference of dimensions, etc. a method which does not lend itself at all well to modern methods of mass production using elaborate machine tools, gages, etc. (Witness the case of colors for paints, dyes, etc. for which no simple, exact means of physical specification is yet possible; as a result of which it is necessary to prepare, at considerable expense, color cards, painted strips, liquid samples, etc. which are difficult to reproduce accurately and are imperfect in many other respects.)

II—*Nomenclature*, or standards which define terms, or establish nomenclature or standard symbols.

1 Standard terms and their definitions
2 Symbols
  a Algebraic—for use in formulas
  b Graphic—ideographs or pictographs
  c Abbreviations.

EXAMPLES: Standard nomenclature for terms used in radio communication (1); E = electric potential in volts (2*a*);—|||— = electric battery (2*b*); Cl = Chlorine; in. = inch or inches (4*c*).

III—*Standards of Size and Form—Dimensional Standards*,[1] or those which establish particular dimensions, or combinations of dimensions, for the construction or working of machines and equipment or their components. The dimensions standardized are usually chosen as:

1 Suiting to the best degree the requirements of existing buildings, equipment, apparatus, machines, tools, or parts, by providing for intermembering or interworking, or interchangeability of parts and supplies.

EXAMPLES: Standardization of screws, bolts, and nuts; ball bearings; electric lamp bases and sockets; leads for pencils using renewable leads; standardization of general or inclusive dimensions, such as clearance outlines of railway moving stock; overall diameter of boilers and tanks, and length and height of radiators, and such other dimensions as determine approximate floor-space requirements or arrangement of equipment.

a A more highly developed form of this type of standard is seen in what may be called the standard component—a specialized machine part or device which may be used in more than one assembly. This type of standardization is particularly common in communication and other electrical industries where a single small standard part may appear in numerous and quite diverse assemblies.

EXAMPLES: A contact spring usable in various telephone and telegraph relays, in a governor for a motor speed control, and in a remote-control key; a bearing bush; a car wheel; a drawer handle suitable both for steel desks and filing cabinets.

NOTE: In dimensional standardization, in cases where accuracy is a factor, some statement of tolerances or allowances is usually necessary in order to give the dimensions practical and definite significance. Systems of tolerances and allowances are a form of dimensional standardization underlying in a fundamental way whole classes of ordinary dimensional standards.

Of the dimensional type, but more far-reaching in scope than others of this class, are basic and underlying standards like Preferred Numbers, which set up uniform series of frequently used numbers diversely applicable as dimensions of size, weight, speed, etc. for all sorts of standardized objects; "Standard Diameters," a sort of Preferred Numbers especially developed to provide a limited number of nominal diameters for all round stock or cylindrical constructional elements so as to require a minimum number of tools (such as drills, reamers, and countersinks), gages, fixtures, jigs, special machines, etc.

[1] Assistant Secretary, American Engineering Standards Committee.

[2] The advantages accruing from standardization in industry are analyzed in detail in a paper entitled, Advantages of Standardization, published in the January, 1925, issue of *The Purchasing Agent*.

[3] The subject of classification of standards was taken up by the second Conference of Secretaries of the National Standardizing Bodies, held in Zurich in July, 1923. A committee of this Conference, under the chairmanship of C. leMaistre, Secretary of the British Engineering Standards Association, drew up a brief outline classification for standards, which it was voted should be submitted to the secretaries of the various national standardizing bodies for criticism and for the setting up of equivalent expressions in English, French, and German, and possibly also in other languages. Dr. Agnew, Secretary of the American Engineering Standards Committee, who is a member of the committee mentioned above, has made many valuable suggestions in connection with the present analysis.

[1] In Germany and in a number of other European countries which follow similar lines in such work, standardization is divided into two major classes: "Normalization" (*Normung*) and Type Standardization (*Typisierung*). The former corresponds in its leading characteristics to our dimensional standardization, which forms by far the largest part of standardization activities in Continental European countries; the latter applies chiefly to the setting up of a planned series of standardized articles, usually on a dimensional basis, such as a complete set of paint brushes from the smallest to the largest sizes entering into commercial use. This work corresponds in some respects to that done by the Division of Simplified Practice under the name of Simplification, to which reference is made later.

2 Combining in a single instrument, device, or practice, needed characteristics of suitability, convenience, capacity, economy, and strength for a given purpose or a group of purposes having common factors. The needed characteristics are expressed in terms of physical and chemical properties, such as mechanical, electrical, optical, chemical, and other definable characteristics.

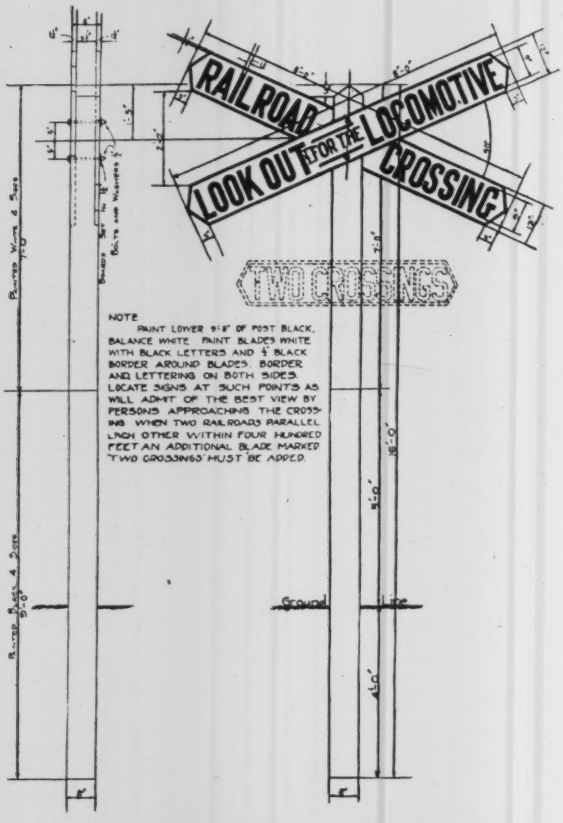

RAILROAD
LOCOMOTIVE
LOOK OUT FOR THE
CROSSING
TWO CROSSINGS
NOTE
PAINT LOWER 9'-6" OF POST BLACK, BALANCE WHITE. PAINT BLADES WHITE WITH BLACK LETTERS AND 4" BLACK BORDER AROUND BLADES. BORDER AND LETTERING ON BOTH SIDES. LOCATE SIGNS AT SUCH POINTS AS WILL ADMIT OF THE BEST VIEW BY PERSONS APPROACHING THE CROSSING. WHEN TWO RAILROADS PARALLEL EACH OTHER WITHIN FOUR HUNDRED FEET AN ADDITIONAL BLADE MARKED "TWO CROSSINGS" MUST BE ADDED.
Ground Line

FIG. 2 FAMILIAR STANDARDS OF THE PICTOGRAPH CLASS (II, 2, b)
(The one above is a dimensional standard also (III, 2), as adopted by the American Railway Engineering Association. (Manual, A.R.E.A., 1921, p. 456.))

EXAMPLES: Standard size and arrangement of printing on letterheads or bills of lading; standard form of tool handle, as for files and broaches; uniform arrangement of lettering and graduations on meters or instruments, to give maximum ease and accuracy of reading due to familiarity and habituation; use of red lamps or lettering as a warning of danger.

IV—*Standard Ratings*, or those which establish a limit of use or operation within which certain requirements as to performance, durability, reliability, safety, etc. must be met.

EXAMPLES: The horsepower rating of an electric motor; The speed rating of a steam locomotive.

NOTE: Ratings require the establishment of numerous collateral conditions to insure definiteness e.g., in the second case, a smooth, straight, and level track, a supply of coal of stated size and quality, fired in a specified manner, etc.

(In one sense ratings are a form of dimensional standardization, using the term "dimension" in the sense familiar to the physicist, of all quantities that are not pure numbers, that is, that are expressible in units of length, mass, time, magnetic permeability, and temperature.)

V—*Standards of Quality:* Specifications setting up standards of purity, strength, elasticity, durability, color, workmanship and other non-dimensional[1] characteristics which determine the industrial or engineering usefulness or appearance of raw or intermediate materials, semi-finished products, or of structures, equipment or machines.[2] This is the class often loosely known as purchase specifications.[3]

EXAMPLES: Specifications for iron ore (raw material)
Specifications for paint pigment (intermediate material)
Specifications for cold-rolled steel bars (semi-finished product)
Specifications for concrete chimneys (finished equipment), in so far as they concern the material of the foundation, selection of cement, aggregate, proportions of the mix, reinforcing rods, lightning rods, and similar items.

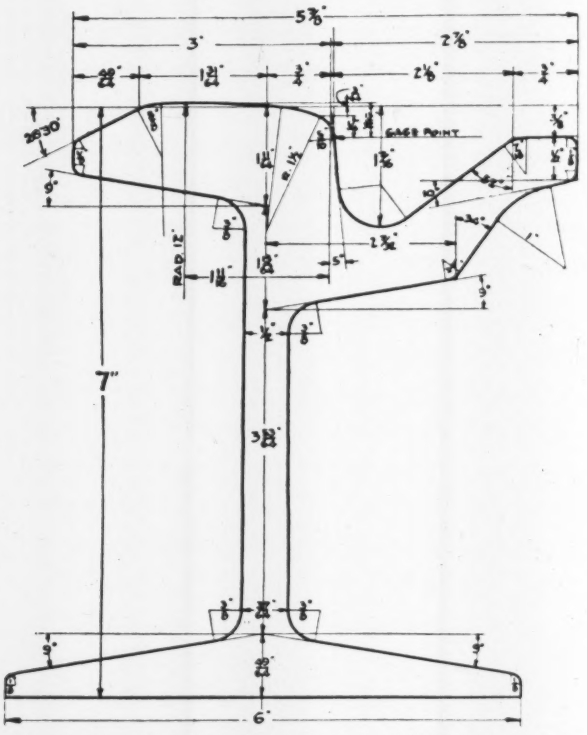


FIG. 3 DESIGN FOR 7-IN. GIRDER GROOVED RAIL USED IN ELECTRIC-RAILWAY SERVICE
(A dimensional standard, Class (III, 1), developed by American Electric Railway Association and approved by A.E.S.C. in 1923, as American Standard.)

[1] Using the term again in its ordinary sense, applying to distances, that is, linear dimensions.

[2] Like the standards of length, electric potential, mass, illumination, etc. described in footnote 3, it is possible to establish concrete expressions for standards of quality, typified by the standard samples of iron ore, steel, naphthalene, sugar, etc. distributed by the Bureau of Standards, which are used as a basis for checking chemical analyses, calorimetric and polarimetric determinations, melting points and fineness (of cement). Such reference standards provide an important control in the quality of industrial products and are thus often used as auxiliaries to written specifications.

A similar though less quantitative instance is found in the Bureau of Standards' Technologic Paper No. 250, "Pulp and Paper Fiber Composition Standards" ("Reference standards, showing the color reactions of common paper-making fibers and standard fiber mixtures with various stains for use in identification and estimation of fiber composition of paper"). These are an unusual sort of standard sample in the form of reproductions of microphotographs of paper fibers as prepared for laboratory examination: showing, for example, the appearance of 100 per cent rag paper, 100 per cent sulphite paper, 50 per cent rag-50 per cent sulphite, and similarly through other combinations including groundwood, soda, jute, manila, etc. By the use of these standards the analyst can compare his visual estimates with standards accurately determined for microanalysis. Such standards may even involve the idea of tolerances, as in the acceptance of limestone lying between two extremes of texture established by samples chosen to represent the limits.

[3] The term "Master Specification" has been used by the Federal Specifications Board for its own published specifications, in the sense that such specifications can be used without additions by all departments and establishments of the Government. Each department may, however, add non-technical and business details that do not alter or conflict with technical and inspection details of the Board's specifications.

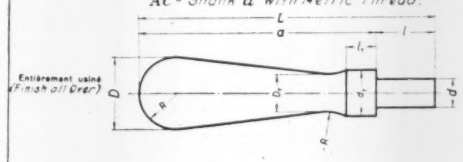
VI—*Standards of Practice:* Establishment of the practice or process best suited to the purpose in hand, to insure the most rapid, most accurate, cheapest, or otherwise most advantageous method of carrying on an operation or process or operating a machine or device. In some cases these are called construction specifications. In others they may be drafted primarily from the point of view of safety to workers, in which case they fall into the class of safety codes, discussed below.

EXAMPLES: Specifications for the method of erecting a steel bridge (construction specification)
Rules for the operation of electric railway substations (operating rules)
Safety code for grinding operations (safety code)

NORMES DE LA SOCIÉTÉ SUISSE DES CONSTRUCTEURS DE MACHINES

Poignées coniques fixes (Fixed Taper Handles) — VSM 16100

AA = Shank d smooth; AB = Shank d with Whitworth Thread; AC = Shank d with Metric Thread.



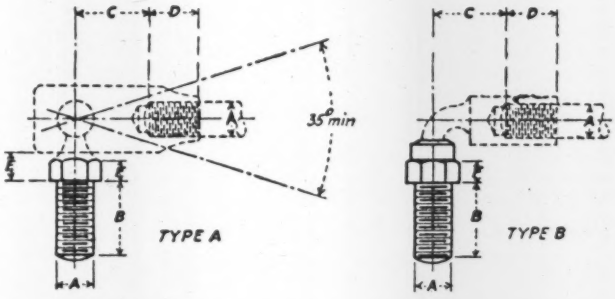
Designation for a Fixed Taper Handle with Metric Thread, D = 25 mm:

FIXED TAPER HANDLE = AC 25 VSM 16100 (INDICATE THE MATERIAL)

DIMENSIONS IN MILLIMETERS

D	a	d Mod. AA Ajustage 0.3	d Mod. AB Filetage Whitw	d Mod. AC Filetage métr	l	L	d_1 Ajustage 0.4	l_1	D_1	R
10	32	4	—	4	8	40	7	4	5	5
13	40	5	—	5	10	50	8	5	6.5	6.5
16	52	7	1/4"	6	13	65	10	7	8	8
20	64	8	5/16"	8	16	80	13	8	10	10
25	80	10	3/8"	10	20	100	16	10	12	12.5
30	96	13	1/2"	12	25	120	19	12	15	15
35	110	16	5/8"	16	30	140	22	14	18	17.5
40	125	16	5/8"	16	35	160	26	16	20	20

S. A. E. Standard



A Diam.	A Threads Per Inch	Hex. Min.	B	C	D	E[1]	F[2] Min.
No. 5	40	1/4	9/32	1/4	1/4	7/32	3/32
No. 8	32	1/4	11/32	11/32	5/16	7/32	7/64
No. 10	32	5/16	13/32	13/32	3/8	1/4	1/8
No. 12	32	3/8	15/32	7/16	3/8	1/4	9/64
1/4	28	3/8	9/16	1/2	7/16	9/32	5/32
5/16	24	7/16	23/32	5/8	9/16	9/32	3/16
3/8	24	9/16	7/8	3/4	11/16	5/16	7/32
7/16	20	5/8	1	7/8	13/16	3/8	1/4
1/2	20	3/4	1 1/8	1	15/16	7/16	9/32

[1]Minimum wrench clearance.
[2]F = ½ A + 1/32.
Dimensions in inches.
Threads are S. A. E. Regular on fractional sizes.

FIG. 4 TYPICAL DIMENSIONAL STANDARDS OF CLASS III, 1, a

(The one above promulgated by the Swiss national standardizing body, illustrates also the use of preferred numbers in dimensional standardization. The dimensions *D*, for instance, lie in a geometric series giving approximately 25 per cent increase of diameter from one size to the next. (See note 1 under III, 1, a.) This design also typifies the use of standard nomenclature (II, 2, c), in the use of the designations AA, AB and AC.
The design below is the Society of Automotive Engineers' standard for ball-and-socket joints.)

Methods of Test are to be classed as process or operation specifications, being standards of practice applicable to the determination of the degree of conformity of apparatus, components, or materials, to quality standards, dimensional standards, or ratings. Methods of test are not, therefore, independent standards of practice, but are to be considered as auxiliary to the setting up and practical use of other standards. Methods of test in turn are sometimes known under two classes:

a For quick, ready, routine use
b For precise work, required perhaps in settling controversial cases (referee methods).

Safety Codes are not a distinct class of standards, but partake of

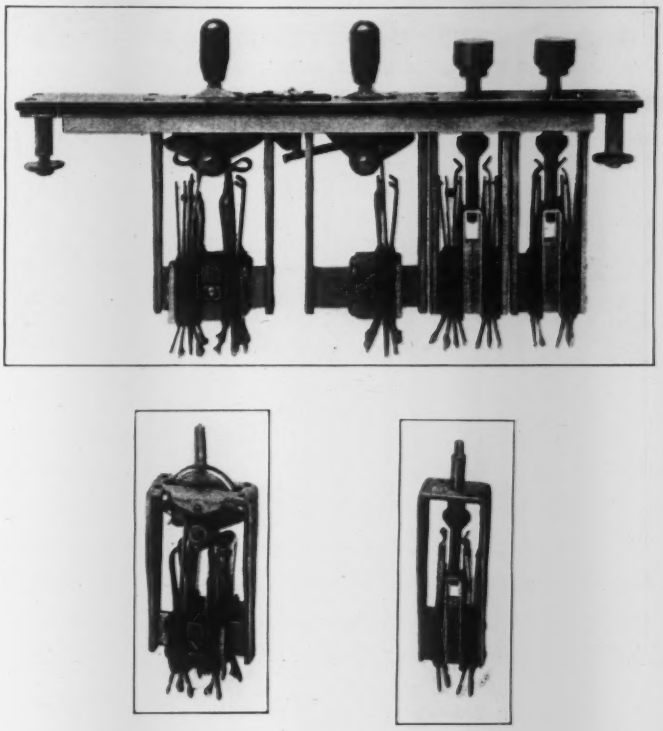


FIG. 5 AN INTERESTING EXAMPLE OF CLASS III, 1, a

(A number of key units used in telephone work, the key springs being standard parts used to build up various spring combinations applying to different circuit requirements. The key units associated with a given circuit may be assembled on a standard key base which is arranged to mount various combinations of units. The upper illustration shows a typical assembly. Photograph by courtesy of the American Telephone and Telegraph Company.)

the characteristics of several of the foregoing, as is suggested under "Standards of Practice."

EXAMPLE: Safety Code for the Construction, Care, and Use of Ladders (A E S C No. 14—1923): requirements covering minimum permissible *dimensions* and *quality* of materials, together with definitions, and instructions for installation, inspection, and use.

SCOPE OF STANDARDIZATION AND SIMPLIFICATION

Simplification, as the term is used by the Division of Simplified Practice of the Department of Commerce, is an elementary or preliminary form of standardization, and may be applied to a number of the above fields by elimination of unnecessary variety of types, forms, sizes, ranges, capacities, qualities, etc. of materials or manufactured products. Simplification is distinguished by the fact that it does not set up new items, but selects, usually on commercial grounds, from a series of items already in existence or on the market. In the practice of the U. S. Department of Commerce, Division of Simplified Practice, the selection is based upon relative consumer demand for the several sizes and varieties entering into production and distribution.

Standardization, on the other hand, may, on occasion, supplant all existing items or practices by new ones, usually fewer in number, where circumstances require such modification of existing practice, or in new fields of development may even set up a standard in advance of practice. An example of this is seen in the proposed

standards for pipe flanges and fittings for working pressures of 1200 pounds per square inch and temperatures of 750 degrees fahrenheit. In this case a carefully evolved standard, developed by engineering methods, is needed in order to make possible and safe, large-scale commercial installation of power-plant equipment for pressures not hitherto applied in industry.

CLASSIFICATION OF STANDARDS BY USE

Standards may be classed on the basis of their degree of acceptance: those in regular customary use being known as "standards," while those in an initial or trial stage are known as "tentative" or "provisional standards." In ordinary course it is assumed that such standards will advance to the status of regular standards.

NORMES DE LA SOCIÉTÉ SUISSE DES CONSTRUCTEURS DE MACHINES

DIAMÈTRES NORMAUX
STANDARD DIAMETERS

Feuille de normes **VSM 15000**

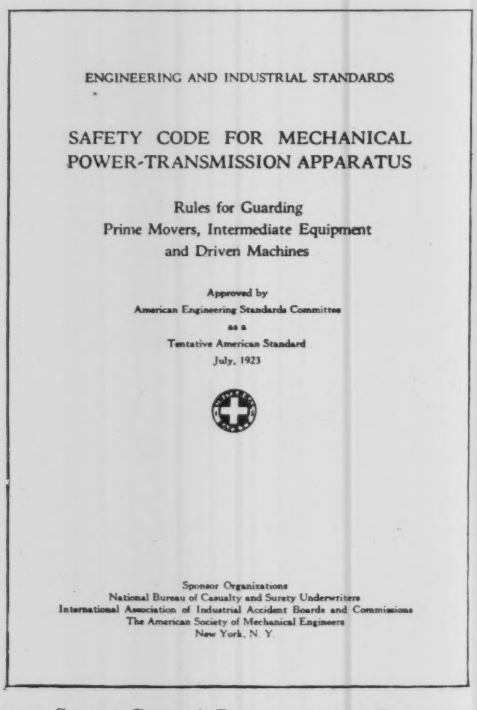
Dimensions en mm

		52								
		55	105	155						
	6									
	7									
	8	58								
	9									
1	10	60	110	160	210	260	310	360	410	460
	11									
1,2	12	62								
	13									
	14									
1,5	15	65	115	165						
	44									
4,5	45	95	145	195						
	46									
	* 48	98								
5	50	100	150	200	250	300	350	400	450	500

Pour les diamètres supérieurs à 100 mm on pourra en cas d'absolue nécessité insérer les échelons 2, 5, 8
* Les diamètres 37 et 47 concernent seulement les roulement à billes.
Les diamètres normaux sont prévus spécialement pour l'emploi de calibres de contrôle et d'outillages normaux

Commission de normalisation du VSM — Les papillons modificatifs sont à coller dans cette case — Masse
Arrêté le 10 Sept. 1919 — No. de classement
Publié le 20 Oct. 1919

FIG. 6 STANDARD DIAMETERS; ANOTHER FORM OF PREFERRED NUMBERS, AS ESTABLISHED BY THE SWISS NATIONAL STANDARDIZING BODY
(See Par. 2 of note under III, 1, a.)


ENGINEERING AND INDUSTRIAL STANDARDS

SAFETY CODE FOR MECHANICAL POWER-TRANSMISSION APPARATUS

Rules for Guarding
Prime Movers, Intermediate Equipment
and Driven Machines

Approved by
American Engineering Standards Committee
as a
Tentative American Standard
July, 1923

Sponsor Organizations
National Bureau of Casualty and Surety Underwriters
International Association of Industrial Accident Boards and Commissions
The American Society of Mechanical Engineers
New York, N. Y.

FIG. 7 TYPICAL SAFETY CODE, A PAMPHLET OF 46 PAGES ON THE SAFEGUARDING OF POWER-TRANSMISSION EQUIPMENT

A further classification of standards is possible with respect to the time and trend of their utilization, thus:

Obsolete	(Designs, practices, etc.)
Obsolescent	(Designs, practices, etc.)
Standard	(Designs, practices, etc.)
Prospective Standard	(Designs, practices, etc.)[1]
Ad Interim Standard	(Designs, practices, etc.)

the latter being intended to bridge an interval between an obsolescent and a current standard, or between a standard and a prospective standard.

In an actively growing and developing industry, all of these classes of standards are often involved. Some may be designated as definitely obsolete (as the bayonet lamp base and socket in house-wiring practice in this country), and others are to become obsolete after the lapse of a certain interval or upon exhaustion of existing stock (as certain types of wiring plugs and the corresponding receptacles). The third class of active standards is that for which no change of application is yet foreseen, while future or prospective standards may be established for utilization after a certain period of time or upon the completion of certain preparatory stages, or of related standardization work in other fields.

RECENTLY another class of steel alloys has gained preëminence. These are the alloy steels commonly known as of the "stainless" or "rustless" type. These steels contain amounts of alloying elements in very much larger percentages than do the usual structural alloy steels. Our fundamental knowledge as to the effect of such percentages in resisting corrosion is even more limited than in the case of the structural steels.

The principle that has heretofore stimulated experimentation in this field seems to be that of equivalence. In the case of high-chromium rustless steels some of the chromium content has been successfully replaced by such elements as copper, nickel, silicon, etc. In such substitution there seems to be the additional advantage, as in the case of copper, of imparting to the steel acid-resisting properties as well as resistance to oxidation.

Reverting to our principle of equilibrium, undoubtedly the phenomena of noncorrosiveness can be traced back to it after we have gained a little more insight into the mechanism of corrosion. Solubility or chemical activity is without doubt a function of the free energy of matter, especially the surface energy. In aqueous solutions, the size of grains of the solute is known to alter the solubility. We may therefore find in the study of free energy an explanation of the relation of noncorrosiveness of such steels to their structure and also of the effect of heat treatment on noncorrosiveness.

The fundamentals of noncorrosive steels may lead us into equilibrium phenomena, not only of the micro constituents, but into the ultra field. The atomic arrangement or introduction of the alloying atoms into the iron lattice may have the effect of changing the surface energy content and equilibrium conditions of the resulting physical grains. We may then consider noncorrosiveness as a function of what we may term "atomic architecture."

On account of the immense economic importance of corrosion in steel metallurgy, as so ably shown by Sir Robert Hadfield, the metallurgist has been stirred to develop processes fundamentally different from the usual steel-making practices, whereby noncorrosive steels can be produced at such cost as to make their application possible for general purposes. This has been accomplished by reducing the alloying element content directly from the raw ore into the finished steel. In this manner large percentages of the alloying metal can be introduced from a very cheap source. Besides the factor of cheapness, by such processes the alloying element is introduced in its nascent and pure state uniformly into the steel, avoiding all tendency to segregation. B. D. Saklatwalla in *Industrial and Engineering Chemistry*, for January, 1925, p. 98.

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[1] The Electric Power Club, in its Handbook, 1922, sets up the following classification of standards, part of which are on a basis somewhat related to the above:

(*a*) Adopted Standards (Divided into three sub-classes)
(*b*) Recommended Practice, the same in time of application as Adopted Standards, but of less degree of influence or weight in industry (Divided into three sub-classes)
(*c*) Suggested Standards for Future Design
(*d*) Departures from Adopted Standards.

These titles, which are sufficiently explanatory, illustrate the growing recognition of the need for careful distinctions between the types and application of standards growing up in highly developed technical industries.

Physical Properties of Water Vapor

THE author attempts to coördinate the results of the recent researches in Munich by Knoblauch, Raisch, and Hausen with those carried out at the Massachusetts Institute of Technology in America, and to present them from the point of view of dynamic functions, using the Fresnel method for this purpose.

The kinetic theory of gases assumes that the average kinetic energy of the movement of translation of molecules is proportional to the absolute temperature θ. Hypothetically this movement of translation is likened to that of a projectile, but unquestionably there is nothing in the way of considering it also as a periodic radial vibration, a hypothesis which permits plotting on the real axis OX the average kinetic energy set into action in the course of the vibratory movement. Expressed in calories this active energy would correspond to the sensible mass heat $\kappa\theta$. It is easy to conceive that this kind of thermal agitation would propagate itself more or less rapidly by an *impulsive* vibratory concussion until an equilibrium between the reciprocal actions of all the molecules present had been established. It is likewise admitted in the current kinetic theory of gases that the molecules are endowed with a kinetic energy of rotation and a potential energy of elastic deformation, the sum of which corresponds to the internal mass heat. The latter, the thermochemical importance of which is predominant, can propagate itself only under the form of a certain *inductive* pull, of which remarkable manifestations are offered by the phenomena of crystallization, allotropic modification, catalytic action, and chemical affinity. This internal mass heat may be considered here as a reactive energy and its value χ in calories may be plotted on the imaginary axis OY.

The total mass heat U can be expressed by $U = \sqrt{(\kappa\theta)^2 + \chi^2}$; it will be represented by the hypothenuse XY. If we designate by φ the angle OXY, then $\kappa\theta = U \cos \varphi$, and $\chi = U \sin \varphi$, and the specific heat, being nothing else but a derivative U' of the total heat U with respect to the absolute temperature θ, will be expressed by

$$U' = \frac{\kappa^2\theta}{U} = \kappa \cos \varphi$$

with κ theoretically constant, except in the case when the additional supplementary work of expansion is not negligible.

When U' increases at the same time as θ it happens nearly always that the angle φ will be decreasing, but the contrary would take place in the liquid phase of mercury where U' decreases in proportion as θ increases. In the particularly important case of liquid water U' remains sensibly constant; hence φ will be practically constant and the total mass heat, $Q = c\theta$, proportional to θ. Now c has been selected as a unit of the quantity of heat, hence liquid water will contain a total number Q of calories practically equal to the number θ of degrees centigrade expressing its absolute temperature.

The author proceeds to apply the above Fresnel notation to an approximative numerical investigation of the typical case of water.

1—*Liquid Water.* Neglecting well-known variations none of which exceeds 1 per cent, one may use, in the notation explained above, the following average numerical values applicable between $\theta = 253$ deg. cent. abs. and $\theta = 638$ deg. abs., this being the range between supercooled water and water at the critical point:

$$\kappa\theta = 0.7071\,\theta; \quad \chi = 0.7071\,\theta; \quad \theta = 1.000\,\theta; \quad \varphi = 45 \text{ deg.}$$

This is equivalent to saying that because of the freedom and mobility of the liquid molecules and undoubtedly also because of the chemical neutrality of the water, the theoretical tendency toward equipartition of energy is satisfied within the entire range of the liquid phase.

2—*Saturated Water Vapor.* It follows from this that at 373 deg. abs. and under normal pressure the total mass heat U of water vapor will be equal to approximately 870.9 calories (the total mass heat of liquid water at 373 deg. is 373 calories; to this should be added the mass heat of vaporization $r = 538.7$ calories, but there should be deducted the external work Apv or $0.0243 \times 1678 = 40.8$ calories). The active component $\kappa\theta$ must remain equal to $0.7071 \times 373 = 263.75$ calories; the second component χ would pass during vaporization from 263.75 to 830 calories (reactive).

If it be admitted that for saturated water vapor under all conditions this value of χ remains practically constant, no matter what θ may be, we may write for the region between $\theta = 273$ and $\theta = 638$ deg. abs., the following:

$$\kappa\theta = 0.7071\,\theta; \; \varphi = 830; \; U = \sqrt{0.5\,\theta^2 + 689{,}900}; \; \varphi = \text{from } 76°57' \text{ to } 61°48'$$

From this the author has calculated the values of Table 1 where

TABLE 1

θ deg. cent.	$\kappa\theta$	χ	U	Apv	L	r_c	r_R	r_H
273	193.04	830	852.15	31.53	883.68	610.68	606.50	.....
298	210.72	830	856.33	33.70	890.03	592.03	589.11	.....
323	228.40	830	860.85	36.07	896.93	573.93	571.66	570.0[1]
348	246.07	830	865.71	38.53	904.24	556.24	554.14	554.1
373	263.75	830	870.90	40.80	911.70	538.70	536.50	538.7
398	281.43	830	876.41	42.88	919.29	521.29	518.73	521.7
423	299.11	830	882.24	44.75	926.99	503.99	500.79	503.8
448	316.78	830	888.40	46.39	934.79	486.79	482.65	485.8
473	334.46	830	894.85	47.83	942.68	469.68	464.30	.....
638	445	830	942	60[2]	1000[2]	362[2]	....	.....

[1] Corrected value. [2] Approximate value.

all the elements expressed in calories are referred to unit mass. For the external work Apv the Zeuner values have been increased from 0.5 cal. to 0.7 cal., because at 373 deg. abs. the now accepted value of v is 1679 instead of 1650 as formerly. The symbol L indicates the total mass energy $U + Apv$, and r_c the calculated heat of vaporization; $L - Q = L - 1000\theta$. r_R and r_H designate, respectively, the heats of vaporization as measured by Regnault in 1847 and Henning in 1909. The diagram given on the next page is derived from the values thus calculated.

3—*Ice.* At 273 deg. abs. and ordinary pressure, the total mass heat U of melting ice is equal to about 193 cal. (total mass heat Q of liquid water at 273 deg. is 273 cal.; deduct from this the mass heat of fusion from 79.6 to 80.3 cal. according to various experimenters; the external work Apv is negligible). The active component $\kappa\theta$ must remain equal to $0.7071 \times 273 = 193.04$ cal. Hence, for ordinary melting ice (ice I) we have:

$$\kappa\theta = 193.04; \quad \chi = 0; \quad U = 193.04; \quad \varphi = 0 \text{ deg.}$$

Since $\chi = 0$ and $\varphi = 0$, there is apparently an equality between two opposite terms of which the reactive component χ is the difference, namely, the kinetic energy of molecular rotation and the potential energy of elastic deformation. In electricity one would say in such a case that the inductance and capacitance being in equilibrium, the reactance and phase displacement are nil.

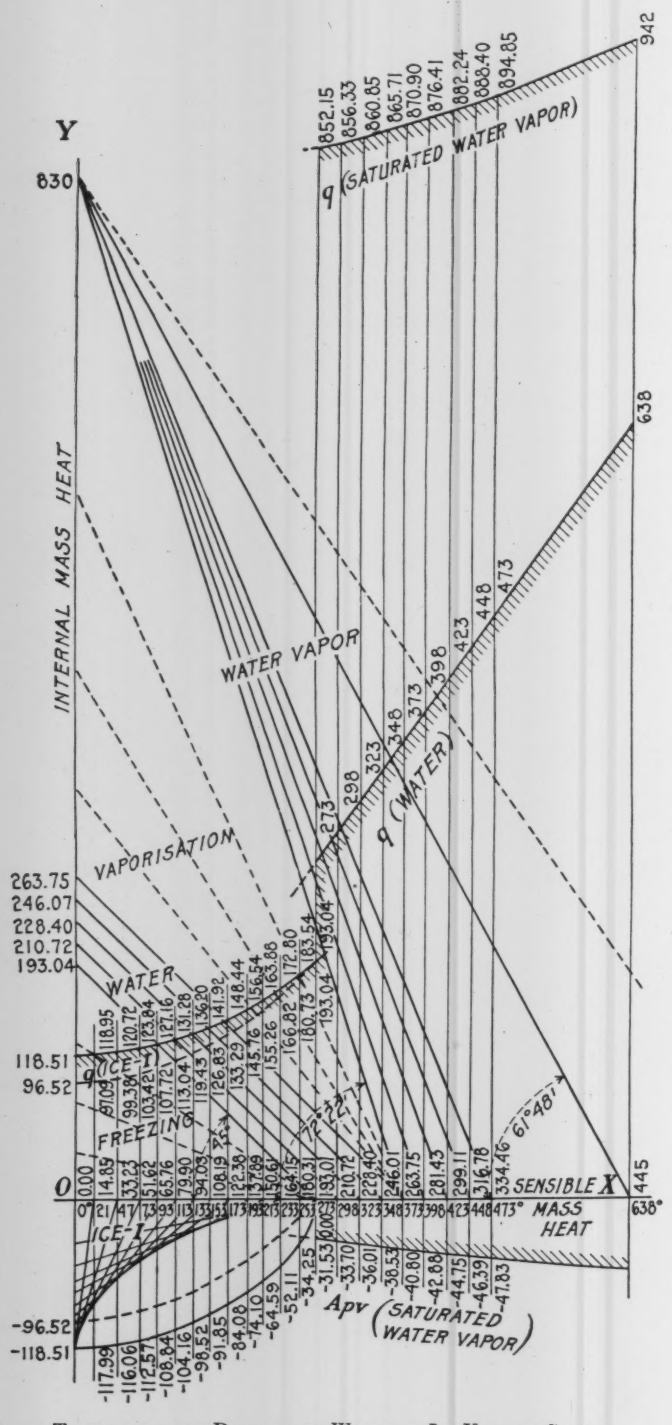
Between absolute zero and $\theta = 273$ deg., the specific heat U' of ice increases very nearly in proportion to the temperature θ. To express this law there is a choice between several empirical solutions, two of which the author mentions, and he shows how the specific heats U' of ice as derived from one of these theoretical methods were experimentally confirmed.

From Table 1 it would appear that a single value of the reactive

component $\chi = 830$ cal. is sufficient in order to obtain for the calculated heat of vaporization r_c a series of values which represent a fairly good compromise between the divergent experimental results obtained by Regnault on one hand and Henning on the other. The publication of the Munich investigation (Knoblauch, Raisch, and Hausen), however, led the author to compute a series of values for χ that would be applicable to the case of saturated water vapor. From these values, given in Table 2, it would appear that the values of the reactive component χ are connected with those of the absolute temperature θ by a hyperbolic relation of the second degree, the developed equation of which is:

$$\chi^2 - 0.2574\,\theta^2 + 0.6\,\chi\theta - 2065\,\chi - 292.8\,\theta + 984{,}300 = 0$$

By means of this equation it becomes possible to retain the main postulate of the author dealing with the equipartition of energy in



THERMODYNAMIC DIAGRAM OF WATER IN ITS VARIOUS STATES
(*q* in this diagram means *U* for ice I, *Q* for water, and *U* for saturated water vapor.)

TABLE 2

θ deg. cent.	r_{KRH}	L	Apv	U	$\kappa\theta$	χ
273	596.8	869.8	31.53	838.27	193.04	815.7
298	583.1	881.1	33.70	847.40	210.72	820.8
323	569.2	892.2	36.07	856.13	228.40	825.1
348	554.8	902.8	38.53	864.27	246.07	828.5
373	539.7	912.7	40.80	871.90	263.75	831.0
398	523.1	921.1	42.88	878.22	281.43	831.9
423	505.0	928.0	44.75	883.25	299.11	831.1
448	484.55	932.55	46.39	886.16	316.78	827.6
473	461.6	934.6	47.83	886.77	334.46	821.2
498	436.0	934.0	49.07	884.93	352.14	811.8
523	408.0	931.0	50.11	880.89	369.82	799.5
548	378.2	926.2	50.95	875.25	387.49	784.8

the liquid phase of water, and it is from this that the value $0.7071\,\theta$ was obtained for the active component. The same calculations can be carried out with reference to the hypothesis of superheated water vapor, but in that case the variation of Apv becomes relatively important; the author does not attempt such calculations because of the fear that he has not sufficient data at his disposal.

The author then proceeds to the discussion of the phenomena occurring during the change of state. He finds it extremely remarkable that during the entire period of the fusion of a body or its vaporization its temperature remains constant, notwithstanding the fact that the material is absorbing very large quantities of heat. It is also remarkable that the specific heat of a body is usually much higher for the liquid phase than for either the solid or the gaseous phase, notwithstanding the fact that by a comparison of various types of thermometers it was established that there is no appreciable difference between centigrade degrees as measured from one end to the other of the temperature scale in the change of state. From this has been derived an empirical distinction between sensible heat which affects the thermometer and latent heat which does not. The Fresnel method of representation, which implies the coexistence of longitudinal (or radial) vibrations and transversal vibrations together with their vectorial composition, resonance, etc. makes it possible to look into these phenomena and to obtain a clear idea of what is going on.

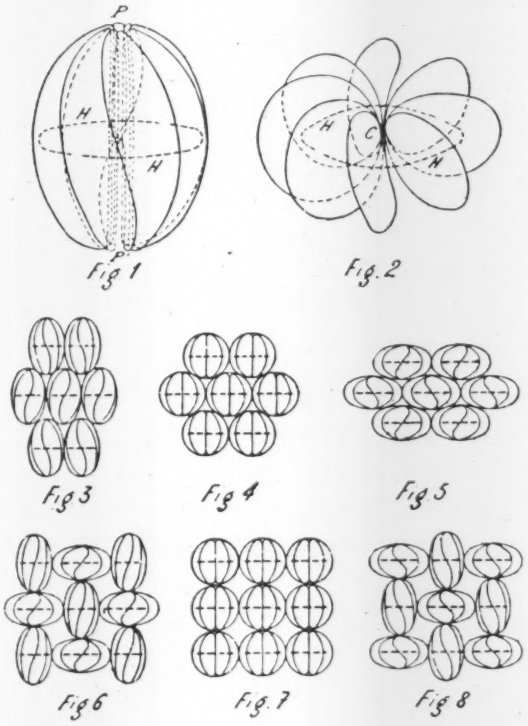
At absolute zero temperature the molecules must be entirely motionless. During the solid period the pulsating movement increases with the temperature but is necessarily accompanied by a rotary torsional oscillation. When resonance of pulsation rotation is reached, the molecules one after another adopt a gyratory motion, which makes it necessary to have an additional supply of energy and as a result of which the two vectors become equal, provided no other cause prevents it. Next comes the liquid period where the two vectors increase simultaneously. Then a new resonance, this time of rotation deformation, accompanied by vaporization and considerable increase of the vector of internal heat. Finally comes the gaseous period when the pulsation of the molecules, which has been momentarily suspended, begins again to increase. Simultaneously with this there occurs a variation of the angle φ measuring the phase displacement. This was negative during the solid period (leading phase displacement), became nil at the beginning of fusion, and turned to positive during the liquid and gaseous period (lagging phase displacement). Electricians will recognize here phenomena analogous to those that take place in a circuit when the resistance, inductance, and capacitance are varied.

The author has been asked (as a result of his previous publication) if some schematic system could not be devised to show the various kinds of vibrations, in particular the pulsation to the growth of which he ascribes the increase in the vector of sensible heat. He does it by using a conception of atom rotors, by which he is enabled to represent the complex molecule of water by an intertwining of two closed electrical circuits, the first consisting of four consecutive coils wound like a Gramme rotor and representing an atom of the element oxygen, and the second consisting of a single coil threaded through the other coils and representing the reunion of two sub-atoms of the element hydrogen. The electric current flowing through any of the elementary coils corresponds to a positive electron; the electrical field about the same coil to a negative electron; and the magnetic field to a Parson magneton.

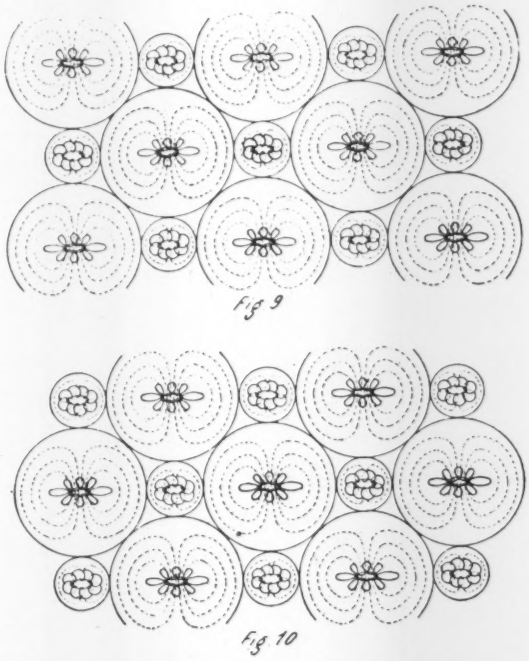
1—*Liquid Water.* An isolated liquid molecule may electrodynamically pulsate between the rotoric form of Fig. 1 (elongated ellipsoid) and the shape of Fig. 2 (flattened ellipsoid). A circular pulsation was noticed by Savart in large drops of water coming from the segmentation of a liquid stream. In this case there

is nothing to hinder all the molecules from pulsating synchronously, Figs. 3, 4 and 5. But if the molecules are united in liquid masses held in more or less rigid walls it must be admitted that the pulsations between contiguous molecules are of an alternating character, Figs. 6, 7 and 8.

2—*Water Vapor.* When distention has forced the coils of the atom of oxygen to draw away from the center *C* of their system



FIGS. 1 TO 8 PULSATING MOLECULES OF WATER
(Figs. 1 and 2, isolated; Figs. 3 to 5, in drops; Figs. 6 to 8, as a mass contained in a vessel.)

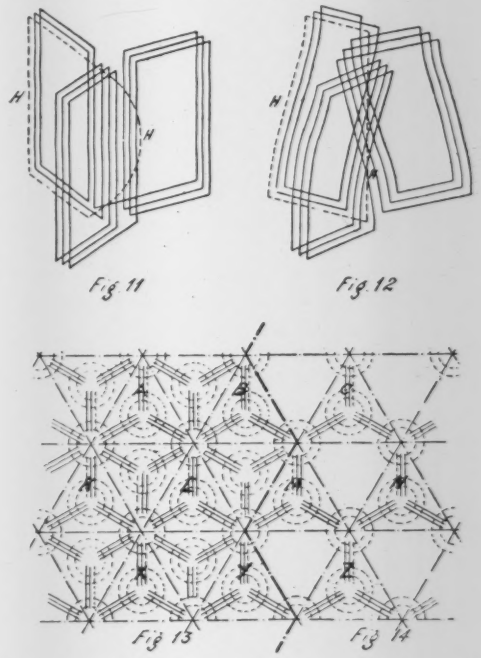


FIGS. 9 AND 10 PULSATING MOLECULES OF WATER VAPOR ALTERNATELY CONTRACTED AND EXPANDED

(Fig. 2), the molecule will be found to have taken the shape of a torus or anchor ring which the coil *HH* maintains in a form somewhat like a belt. With this new state there appear external fields whose intensity depends on whether the molecule is more or less expanded. These fields exert a repulsive action on each other, and Figs. 9 and 10 show how the molecular pulsation may be then conceived as occurring under constant pressure and volume.

At a certain degree of distention the spiral *HH* will break into its two elemental fragments. This will be dissociation, the process inverse to that which gave rise to combination.

3—*Ice.* If a small rotoric model of the molecule *OHH* be wound with coils of rectangular form, it will be found that they could very easily be located by threes in accordance with the bisector planes of a triangular prism (Fig. 11). It will also be found that pulsation may take place by an alternative torsion *in situ* of the coils thus formed (Fig. 12). Other polyhedric involutions are possible, but the crystalline arrangements formed by right prisms having an equilateral triangle as a base (Figs. 13 and 14) have a manifest



FIGS. 11 TO 14 PULSATING MOLECULES OF ICE AND THEIR CRYSTALLINE ARRANGEMENTS

analogy with the characteristic forms visible to the eye in ice, snow, and hail.

In concluding his article the author advocates a greater use of electrodynamic concepts in thermodynamics. (Alfred Lartigue, Chief Engr. of the Tramways of the French Thomson-Houston Co. in *Chaleur et Industrie*, vol. 5, no. 54, Oct., 1924, pp. 501–506, 14 figs., *t*)

Short Abstracts of the Month

AERONAUTICS

Application of the Flettner Rotor-Ship Principle to Aeronautics

THE author expresses the belief that the application of the Flettner rotor-ship principle might produce enormous "wing" loadings combined with low landing speed. It is doubtful whether the actual efficiencies in terms of lift/drag would be better, but this would not matter much if very high lift could be obtained. It is suggested that the rotors might be used as wings for airplanes, or, what is perhaps as likely, in a sort of helicopter. (*Flight*, vol. 16, no. 48/831, Nov. 27, 1924, p. 741, 3 figs., *g*)

ENGINEERING MATERIALS (See also Special Processes: Large-Size Hammer-Welded Pipe)

Blue Asbestos

BLUE asbestos is known scientifically as crocidolite and is found in Griqualand, South Africa. As compared with ordinary white

asbestos the fibers are said to be longer and have a higher tensile strength; they are also much lighter in weight. It is said that it does not deteriorate and lose its fibrous condition under the highest temperatures.

Blue asbestos is particularly suitable for making mattress pads. These are made without any filling or addition, the material being spun and woven like ordinary cloth. Such mattresses have been used on locomotives next to the boiler plates under the outer metal cover. (*The Foundry Trade Journal*, vol. 30, no. 431, Nov. 20, 1924, p. 443, *d*)

FUELS AND FIRING

Maclaurin Process of Making Smokeless Fuel

THE process is of interest as the Gas Department of the Glasgow Corporation is erecting a battery of five Maclaurin producers.

It is claimed that the Maclaurin process can produce from any kind of bituminous coal a semi-coke fuel which may contain down to about 4 per cent of volatiles and which is smokeless when burned on ordinary grates. It also gives a gas which can be used to fire boilers or to supply houses. Furthermore, oils are recovered at the rate of about 20 gal. per ton of coal.

The temperature in the Maclaurin producers can be kept down to, say, 650 deg. cent. The semi-coke produced resembles in size the lumps of coal which go into the plant. The producer is described in some detail in the original article. (E. Kilburn Scott in *Combustion*, vol. 11, no. 6, Dec., 1924, pp. 438–440, 2 figs., *d*)

INTERNAL-COMBUSTION ENGINEERING

Supercharging at Low Speeds

THE application of supercharging on touring cars depends on the ability to use it at comparatively low engine speeds, as even with present engines modern cars can develop higher road speeds than

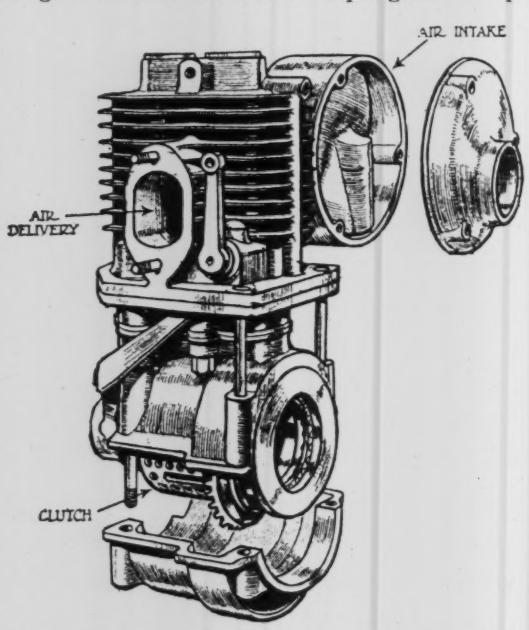


FIG. 1 BLOWER UNIT OF THE MERCEDES SUPERCHARGED CAR WITH THE LOWER PART OF THE CLUTCH CASE REMOVED TO SHOW THE DRIVING BEVEL AND CLUTCH

the average motorist needs. Supercharging is necessary to make touring cars perform better without changing gear, which again means at low speeds.

The first to employ superchargers on standard touring chassis was the German Mercedes Company. On the new model the supercharger may be brought into action at a speed of 10 m.p.h. on top gear. The article is chiefly devoted to this car. While the supercharger is intended to eliminate the use of gears, the chassis is actually equipped with four-speed unit gear box. The blower unit is shown in Figs. 1 and 2. It is situated at the front of the engine and is driven from the nose of the crankshaft. It is brought into operation only when the accelerator pedal is depressed past the full throttle position. The spindles of the two lower blades are mounted vertically and at their lower ends carry small gear wheels meshing with one another so that the blades revolve in opposite directions. One spindle also carries a bevel pinion meshing with the driving bevel, the ratio of the gearing being approximately three to one.

The normal fuel feed is by means of a vacuum tank on the dashboard, and incorporated with this is a small auxiliary tank. When the supercharger is brought into use the depression in the induction manifold is replaced by a pressure and this is communicated to the auxiliary tank, suitable valves being fitted to this and to the vacuum tank to prevent the escape of pressure. The pressure is, of course, balanced throughout, including the carburetor.

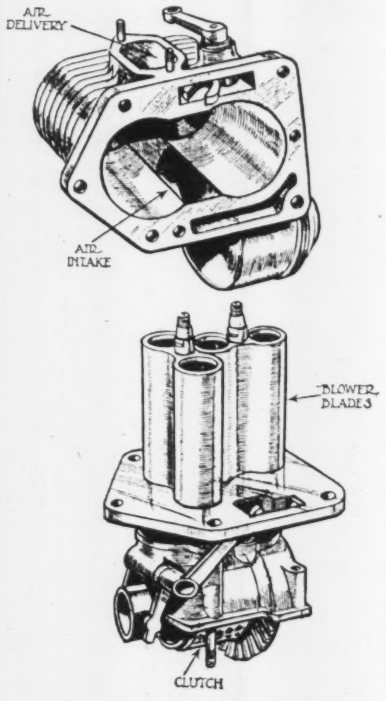


FIG. 2 BLOWER OF MERCEDES SUPERCHARGED CAR WITH CASING REMOVED TO SHOW STEEL BLADES (CLEARANCE BETWEEN BLADES AND CASING VERY SMALL)

The original article gives data of road tests performed with the Mercedes standard chassis by the staff of *The Autocar*, a British automobile journal. Of particular interest are acceleration tests where with the supercharger on top gear the car accelerated from 10 m.p.h. to 30 m.p.h. in 10 sec., and without the supercharger in 13 sec. In road tests increased flexibility was found. For example, on several occasions the car was deliberately slowed down on a hill to 10 m.p.h. and got up to speed on full throttle with the supercharger. Apart from the curious noise made by the blower when in use, the car ran very quietly. (*The Autocar*, vol. 53, no. 1519, Nov. 28, 1924, pp. 1103–1106, illustrated, *d*)

Compression in Gas Engines

AN EXTENSIVE article of considerable interest, presenting data of an experimental investigation. Because of lack of space only the main conclusions can be given here.

1 When operation in an engine is studied, it is important to ascertain whether there are not leaks of sufficient magnitude to falsify results of calculation, particularly when the engine is of small dimensions or of slow speed.

2 If the engine operates properly the state of the gas after the compression is essentially the same as if the compression were adiabatic.

3 The final state of the gas is related to its initial state in accordance with the following equations:

$$\frac{p_1}{p_0} = \left(\frac{v_0}{v_1}\right)^m ; \quad \frac{T_1}{T_0} = \left(\frac{v_0}{v_1}\right)^{m-1}$$

where m differs but little from 1.38. All other things being equal, m is the greater:

a When the power developed by the engine is greater;

b When the initial temperature of the mixture admitted to the cylinder is lower; and

c When the weight of the mixture admitted is the greater.

The value of the exponent m can be calculated from the indicator diagram by means of the equation

$$\frac{p_1}{p_0} = \left(\frac{v_0}{v_1}\right)^m$$

The final pressure p_1 can be easily measured from the diagram, but special processes are necessary to determine the initial pressure p_0. Once m has been determined, it becomes possible to deduce with sufficient precision the increase in the internal energy of the gas and the mechanical work during the compression. It is impossible to utilize m for purposes of computing the exchange of heat with the walls, as by this method it is possible to make an error even in the direction of the interchange. It is also necessary to bear clearly in mind the intermediary points of the diagram.

5 A substantially precise indicator diagram would permit calculating the temperature of the gas at the end of the intake stroke.

6 In a single-acting engine the temperature of the walls decreases strongly from the cylinder head to the opposite end of the cylinder. In order to compute the action of the walls it is not enough to measure the wall temperature at any point; it is necessary to determine the temperature at a number of points and deduce by calculation the average temperature for each position of the piston. This average temperature may be directly deduced from the consideration of the compressive stroke, provided a substantially exact indicator diagram is available. The expansion curve does not help much in the determination of the average temperature, because the shape of this curve depends on the rapidity of the combustion reaction as well as on the wall effect. The average temperature computed from the compression curve may be used to determine the whole effect during the expansion. (A. Jadot, Chief Engr. of the Mechanical Laboratory, School of Mines at Mons, in *Revue Universelle des Mines*, 7th series, vol. 4, nos. 2 and 3, Oct. 15 and Nov. 1, 1924, pp. 62 to 88 and 122 to 148, 20 figs., *ecA*)

MACHINE DESIGN

Stress Distribution in Crankshafts and Its Relation to Crankshaft Failures

DATA of extensive tests on airplane and submarine crankshafts carried out at the Naval Engineering Experiment Station, Annapolis, Md.

In a crankshaft with unrestrained journals under uniform journal torque, the stresses in journals and pins are purely torsional and the stresses in the webs are purely transverse bending.

In a crankshaft with restrained journals under uniform journal torque, restraint of lateral movement of journals may or may not cause torsional stress in the webs. Whether such stress is produced depends on the type of shaft. In a four-throw, three-bearing shaft, web torque is not thus produced. In a four-throw, five-bearing shaft or in a six-throw, seven-bearing shaft, web torque is thus produced.

In a shaft of a type subject to web torque an approximate estimate of web torque may be made by multiplying the value for journal torque by $l/2R$, in which l represents the distance between the axes of the two pins adjacent to a web and R the distance between axes of pin and journal.

Study of typical airplane-crankshaft failures shows that when the calculated transverse web-bending stress is less than the calculated resultant stress in the web due chiefly to torque, fracture starts at a reëntrant angle between a web and either a pin or a journal. Such fractures are not due to transverse bending stresses.

In a few crankshafts of old design the calculated transverse bending stress in the web is greater than the calculated resultant shear stress. Such shafts may fail by transverse bending fracture of a web.

In marine and submarine crankshafts with few exceptions the nominal stress distribution is much more uniform than in airplane shafts. Such shafts, if they contain radial oil holes, usually fail in a journal, the crack starting in an oil hole. If oil holes are absent they may fail in a web.

In radial oil holes in shafts the stress concentration varies somewhat with the class of steel used. In the class of steel used in airplane crankshafts the stress concentration is about two to one.

It is desirable that crankshafts be so designed that, with web torque calculated as described, the stress distribution will be as uniform as possible. (D. J. McAdam, Jr., Metallurgist, and J. F. Wohlgemuth, his assistant at the Naval Engineering Experiment Station, Annapolis, Md., in *Journal of the American Society of Naval Engineers*, vol. 36, no. 2, May, 1924, pp. 244–281, 29 figs., *epA*)

MACHINE PARTS AND DESIGN

Tentacular Leather Belting

DESCRIPTION of a suction type of belting which has been known in Europe for some time and was first shown in this country at the National Exposition of Power and Mechanical Engineering held in New York in the early part of December, 1924. The belting is made up of oak-tanned leather, to the under surface of which are attached narrow longitudinal strips of soft and spongy chrome-tanned leather held in position by rivets. The depressions or hemispherical pockets in the strip having the inside of the hollow rivet as bottom are intended to act as suckers and cause the adhesion of the belt to the pulley. The latter is also claimed to be increased because of the spongy chrome leather which is treated with tallow. (*The Iron Age*, vol. 114, no. 25, Dec. 18, 1924, p. 1601, *d*)

MACHINE SHOP

Increasing Capacity of Turret Lathe by Offset Chuck

DESCRIPTION of the practice of the Coldwell Lawn Mower Co., Newburgh, N. Y., manufacturers of lawn mowers, where large disks have to be handled. Multiple-spindle machines are ordinarily limited in their use to work which is less in diameter than the distance between spindle centers. To handle disks larger than this the chuck on the far side of the machine is provided with extension-type offset jaws which overlap the work chucked on the near spindle. Tools are so set in the turret on the far side as to compensate for this difference in work level. It is claimed that in comparison with the former method of doing this work in a single-spindle machine the production has been increased about 90 per cent from one machine and one operator.

To facilitate stopping of the spindle when necessary to rechuck in a screw machine being used on chucking work, a novel brake has been developed. This was done without any great cost for special parts and without materially altering the standard construction of the machine. This tool is of the friction back-geared type. On the class of work in which the machine is employed open belt speeds are used, so that back gears are not required. The spindle gear, however, is used as a brake, in that it is held stationary and the friction pulled into it, when it is desired to make a quick stop for changing the work. Holding the gear is accomplished by a brass gear sector, of the same pitch as the gear, attached to the inside of the headstock casting. This, meshing with the spindle gear, locks it in place. When it is desired to use the friction back gear the gear sector may be removed, thus converting the machine back to standard. (L. S. Love in *The Iron Age*, vol. 114, no. 24, Dec. 11, 1924, pp. 1529–1531, illustrated, *d*)

MARINE ENGINEERING

Tests of Marine Boilers

DATA of tests of water-tube and Scotch marine boilers, of interest because this appears to be the first time that tests of these two types of boilers have been carried out on units of nearly the same capacity by the same organization and by similar methods. Because of lack of space only some of the results of this interesting investigation can be reported here.

The results of the evaporative tests on the three water-tube boilers show that the slight difference in efficiency is due to difference in design.

At the rate of combustion of 1000 lb. of coal an hour the stoker used 500 lb. of steam an hour. When the rate of combustion was increased to 2400 lb. of coal an hour the steam used by the stoker increased to only 600 lb. an hour. The steam pipe and the cylinder of the stoker were not covered with insulating materials, and most of the steam was condensed because of excessive losses in radiation without doing any work in the cylinder, as is evident from the small increase in the consumption of steam when the rate of combustion was more than doubled. With the cylinder and the steam line well covered the steam consumption of the stoker could probably be reduced to less than 1 per cent of the steam made in the boiler.

Extensive study of the composition of furnace gases in the three

boilers when burning coal showed conclusively the necessity of supplying air over the fuel bed in order to insure complete combustion.

The results of the measurements of gas temperature showed conclusively that it is impossible to ascertain average temperature by placing only one measuring instrument in any cross-section of the gas stream. The variation in temperature in the first pass was about 1000 deg. fahr.; in the stack the temperature at different points differed over 100 deg. fahr.

The results of temperature measurements in boiler-furnace walls showed that a good insulating substance may offer about five times as much resistance to heat flow as ordinary firebrick.

Measurements of the circulation of water in the boiler tubes showed that in the upper third of the tubes in the four-pass boiler the flow of water was from the rear to the front; in the lower third the flow was in the reverse direction. The water in the middle third had no general direction of circulation, the flow being sometimes in one direction, sometimes in the other, and at all times very sluggish.

Heat passed from the gases to the water more rapidly with retarders in the tubes than with no retarders in the tubes for the same rate of flow of the flue gases and the same apparent mean temperature difference between the gases and the water. The retarders were made of thin strips of sheet iron a little narrower than the diameter of the tubes, twisted to make two and one-half turns in the length of the tubes. With retarders installed, heat was transferred to the tube surfaces more readily, and when coal was burned the temperature of the gases leaving the tubes was 60 to 100 deg. fahr. less than with no retarders installed; during the oil tests their temperature was 80 to 120 deg. fahr. lower. With oil as fuel the retarders raised the thermal efficiency of the boiler about 4 per cent and with coal as fuel, 2.5 per cent. The retarders did not appreciably increase the required draft, and apparently no more soot was blown from the tubes when they were installed.

Tests with the brickwork ring in the opening from the furnace to the combustion chamber were also carried out. It was found that when the Schutte & Koerting burner with and without the ring was used, the tests gave no evidence of a change in the thermal efficiency, flue-gas temperature, combustion-chamber temperature, or excess air, that might be ascribed solely to the brick ring; but for a series of four tests with the Todd burner, two with the brick ring and two without it, the thermal efficiency was found to be about 2 per cent higher for the two tests with the brick ring. This higher efficiency was due to less excess air and lower flue-gas temperature. Possibly the brick ring, by reducing the area through which the gases flowed, increased the rate of mixing and enabled the oil to be burned with less excess air; but, on the other hand, the difference in the air supply may have been due to the manipulation of the air regulators. The gas samples taken from the combustion chamber indicated that the oil could be burned with somewhat less excess air with the brick ring installed. Calculations are also presented to show the effect of the retarders on rates of heat transfer in the tubes (pp. 298–302). (Henry Kreisinger, John Blizard, A. R. Mumford, (Mems. A.S.M.E.), B. J. Cross, W. R. Argyle (Mem. A.S.M.E.) and R. A. Sherman in *Bureau of Mines Bulletin*, no. 214, 1924, pp. 1–309, 165 figs., *etA*)

New System of Electrically Driving Ships and Auxiliaries

THIS is a constant-current system in which the current for the auxiliaries is produced by a generator with fixed brushes and the voltage varies automatically according to the external load.

The article describes in detail the windings used and the action of the machine, which is rather complicated. With this system, in which the current is kept constant while the voltage rises in accordance with the load, fuses, the usual switchboards, resistances, and controllers are dispensed with and speed control and reversals can be carried out with ease. These motors are particularly applicable to winches. The motor will maintain full tension on the rope for any length of time with the armature at a standstill, and will take up slack automatically so that the load can be held in mid-air without the use of a brake. (Gilbert Austin, before the Institution of Engineers and Shipbuilders in Scotland, Nov. 18, 1924; abstracted through *The Engineer*, vol. 138, no. 3595, Nov. 21, 1924, p. 580, 3 figs., *d*)

MEASURING APPARATUS

Theory of a Bourdon Tube Pressure Gage and an Improvement in Its Mechanism

THE author attempts to prove mathematically and experimentally that the free end of a Bourdon tube is displaced proportionally to the pressure in the tube and that the displacement is very nearly a straight-line one. Equations are given to show the amount and direction of displacement in tubes generally and in sufficiently flat and thin-walled tubes in particular. Two of the equations are independent of the form of the cross-section and the material of the tube. The author shows further theoretically and experimentally that in an ordinary mechanism the indicating needle does not move proportionally to the pressure within the tube. To correct this he proposes the use of the mechanism shown in Fig. 3, in which it is claimed that the indicating needle moves proportionally to the pressure within the tube with great accuracy,

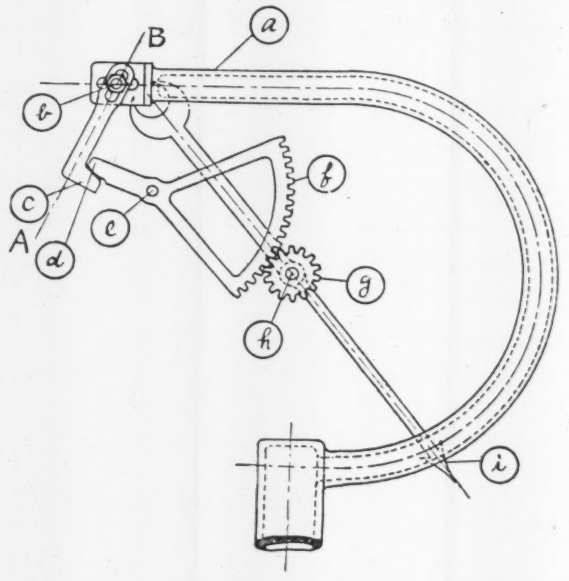


FIG. 3 IMPROVED BOURDON TUBE PRESSURE GAGE

which makes it possible to have a uniform graduation of the dial plate.

Referring to Fig. 3, the author shows that the maximum deviation of the displacement of the needle from proportionality to the pressure in the tube is only 4 lb. per sq. in. or 0.27 per cent of the capacity of the gage. In this mechanism a is the Bourdon tube and c a single-toothed rack bar fixed to the end piece of the tube in the direction AB of the motion of the fixing bolt b, the direction AB being obtained from an equation given in the original article. The rack gears with a single-toothed pinion d, which can rotate about the pin e with a spur wheel f, and this spur wheel gears with a spur wheel g fixed to the spindle h of the indicating needle i, and a hair spring is applied to the spindle h so as to allow the rack and pinion and the wheels to be always geared.

In this mechanism, when the pressure in the tube varies, the rack bar moves along its length, the pinion d and the spur wheel f rotate about the pin e and the spur wheel g and the needle i about the spindle h, and the displacements of these elements are proportional to the variation of the pressure in the tube.

This mechanism was tested between pressures of 0 and 400 lb. per sq. in., and from the results a straight-line formula was obtained by the method of least squares. This formula is $p = 0.1544\alpha - 3.397$, where p is the pressure in the tube in lb. per sq. in. and α the angular displacement of the needle in minutes. Among other things the question of strength of the Bourdon tube is treated in the paper. It also gives a formula and curve expressing the relation of the pressure within the tube and the displacement of the indicating needle. The curve is approximately a straight line, its deviation therefrom being a maximum at pressures of 5 lb. and 200 lb. per sq. in. (Chido Sunatani in *Technology Reports of the Tohoku University*, vol. 4, no. 2, pp. 19–60 (69–110), 20 figs., *d*)

MOTOR-CAR ENGINEERING (See also Internal-Combustion Engineering: Supercharging)

Atkinson Steam Wagon with Uniflow Engine

DESCRIPTION of a British steam truck of six tons capacity. The general layout is of the undertype steamer. The boiler is at the extreme front of the chassis with the engine slung beneath the frame. The boiler—of the vertical type with cross water tubes—is of simple design with no riveted joints. Both the outer shell and the firebox are welded by the oxy-acetylene process, the former having a circumferential joint just beneath the level of the tubes. The firebox is welded to the lower part of the shell and has two openings, one for firing and the other for clinkering. The upper portion of the boiler shell is made detachable to facilitate the insertion of the tubes and inspection or repair.

Coke or steam coal is the usual fuel, and fuel must be added every mile or so. The feedwater heater is bolted to the footplate and consists of a cylindrical cast-iron body to which is attached a bronze header carrying a coil of copper pipe through which passes the water delivered by the engine pump. Exhaust steam enters the heater casing from below and leaves from the side, passing thence to the funnel. The feed heater serves also to silence the exhaust and reduce the pulsations in the funnel.

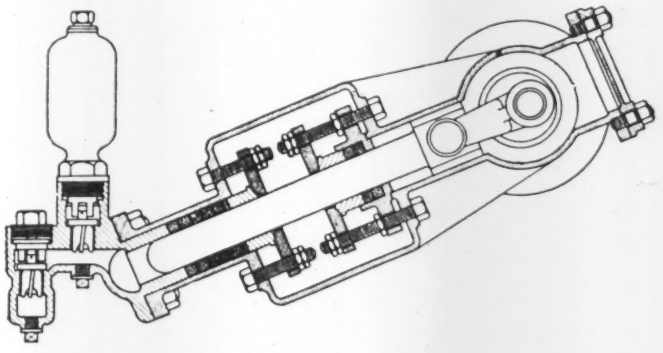


FIG. 4 BOILER-FEED PUMP

The engine, which is extremely simple in design, is of the double-acting uniflow type with two horizontal cylinders having a bore and stroke of 7 in., and 10 in., respectively. The steam is admitted through ball valves controlled by cams and long tappet rods, the exhaust being through ports at mid-length of the cylinders uncovered by the pistons when they approach the end of their stroke. No change-speed gear is provided, the engines being sufficiently large to furnish a high torque at low speed, while the road speed is limited by the ability of the boiler to supply the engine with steam. The general arrangement of the engine and some of the details of the boiler with feedwater system are shown in the original article.

Long double-ended pistons of cast iron are fitted with three rings at each end. Interest attaches to the provision within the pistons of sliding valves which relieve the excessive compression present in a non-condensing uniflow engine, this ordinarily necessitating the use of a very heavy flywheel.

Superheated steam being used, the condensation in the cylinder is very slight, so that on the closing of the exhaust ports the cylinders remain full of dry steam at slightly above atmospheric pressure. During the exhaust stroke this steam is compressed, and as the clearances are very small, unless some means of relief were provided the engine would refuse to run under light loads. It being out of the question to fit a large and heavy flywheel, relieving valves are provided within the pistons. These enable the steam to escape to the exhaust port during the compression stroke when running under such conditions that the pressure on the live-steam side of the pistons is lower than that due to the compression.

Each end of the piston is bored to take a short sliding piston valve, the enlarged head of which seats on a shoulder at the mouth of the main piston, but has a small radial clearance. Three shouldered steel bolts connect the two piston valves and permit them to travel together about $^1/_{64}$ in., so that when one valve head is seated the other is clear. There is therefore a steam passage through the annulus and over the seat into the interior of the main piston. As the waist of the main piston is drilled with a number of holes, communication is thus established between the cylinder and the annulus around the piston. Therefore during such portion of the stroke as the annulus is over the exhaust port in the cylinder wall, steam can escape to the atmosphere.

While the steam pressure in the working end of the cylinder exceeds that of the exhaust steam which is being compressed in the other end, the piston valve on the live-steam side will remain seated, that on the exhaust side being open and permitting the steam to pass through the piston to the exhaust pipe. Under all conditions of running there will be a certain amount of compression to afford the desirable cushioning effect, as when the main piston covers the exhaust port the relief valve becomes inoperative. In practice this arrangement functions excellently, the wear of the parts being negligible. No spring rings are fitted in the piston valves, but shallow grooves in the well-fitting barrel portions serve to keep them steamtight by the well-known "dirt and water" seal.

On the near side of the engine is arranged the boiler-feed pump, this being of the single-acting type with a ram $1^1/_2$ in. diameter by $1^3/_4$ in. stroke. Driven by an eccentric pin on the end of the crankshaft through a short connecting rod, the ram works in two packing glands, one of these retaining oil in the eccentric housing. The water-gland stuffing box is exceptionally long, and both glands are retained by studs having nuts which bear on dogs with spherical seatings on the glands. On the side of the pump casing is a large door through which the glands may be adjusted or repacked, the clearance between the studs being just sufficient to enable the lock nuts to be removed. The pump connecting rod is of cast steel with a bronze bush at the big end.

Flat-faced valves with wing guides are fitted, the wings being set at a slight angle to cause the valves to turn and wear evenly on their seats. Above the suction valve is a screwed plug, and above the delivery valve is an air vessel, which serves also to limit the valve lift. The valve seats are formed in a bronze casting which can be detached from the pump body casting.

To relieve the glands of all side thrust, the ram has a slipped portion of increased diameter, the slipper working in a bored-out guide formed in the pump-body casting. As in the case of the engine connecting-rod guides, no provision is made for adjustment, but the life should be considerable before renewal becomes necessary.

A by-pass device is provided to enable the driver to limit the amount of water fed to the boiler by the pump. (*The Automobile Engineer*, vol. 14, no. 196, Nov., 1924, pp. 352–361, illustrated, *d*)

POWER-PLANT ENGINEERING (See also Marine Engineering: Tests of Marine Boilers)

Regenerative Feed Heating by Superheated Steam

THE author attempts to disprove the statement made by some writers that the use of superheated steam extracted from the higher pressure stages of a turbine for feed heating is essentially uneconomical on purely thermodynamic grounds. He claims that the decision whether or not to adopt this system has to be arrived at by the exercise of judgment in exactly the same manner as in the case of heating to lower temperatures with saturated steam, i.e., after the consideration of all the factors having any influence: not only the heat balance of the complete cycle with due allowances for heat losses and the imperfections of the appliances that can be used in practice, but the effects of working at partial loads and of the increased cost and complication of the plant.

He discusses the process of regenerative feed heating in general with references to a steam-turbine plant. The well-known Rankine cycle is represented on the temperature-entropy diagram in Fig. 5 by *ABCDEA*. In this cycle, the steam during expansion is superheated until the condition represented by *L* is reached; if at the point *G*, say, some of the steam is withdrawn from the turbine, it may be used to heat the feedwater, the final temperature of the feedwater being—in the ideal case—the same as at *G*. The amount of steam extracted is exactly that sufficient to heat the feed from *A* to *K* on giving the water the whole of its available heat, i.e., its latent heat at the extraction pressure. The heat required to generate steam in the boiler is reduced on account of the higher feed temperature; the work done in the turbine per

unit of steam supplied is also reduced owing to some of the steam being removed before it has reached exhaust pressure, but it will be found that this decrease in work is more than counterbalanced by the saving in the boiler room. Thus the result is an increase of thermal efficiency. If the extraction of steam and the heating of the feedwater are carried out in an indefinite number of stages between the temperatures T_A and T_K, it may be shown that if GH be drawn parallel to the "water line" AK, then the decrease of work done in the cycle is numerically equal to that represented by the area GEH. It should be noted that the line GH does not represent the successive conditions of the steam, either that in the turbine or that in the heaters; the sole meaning of the line GH is that the area GEH shows numerically that work which the extracted steam would have done had it remained in the turbine. For that portion of the cycle below KG, the heat supplied from an external source is shown by the area under KG, and the work done is shown by $KGEA$ minus GEH, i.e., by $KGHA$. These quantities are the same as the heat supplied and work done in a Carnot cycle

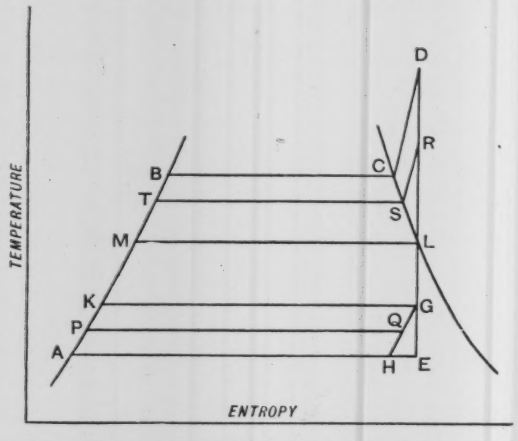


FIG. 5 RANKINE TEMPERATURE-ENTROPY DIAGRAM APPLIED TO CONSIDERATION OF REGENERATIVE FEED HEATING BY SUPERHEATED STEAM

having the same temperature limits. In the ideal case, therefore, that part of the cycle below T_K is perfect in efficiency. If the regenerative feed heating thus effected is carried up to higher temperatures, up to T_M, say, the "perfect" part of the cycle is extended and the efficiency of the whole is increased.

The view is held in some quarters that—quite apart from practical considerations—the limit of this gain of efficiency is reached when the extraction pressure has been raised to that of the point L, where the steam in the turbine has just lost its superheat, and that to carry the feed heating further by means of steam extracted from stages where it is still superheated results in an essential thermodynamic loss. The reason advanced for this view is that the use of superheated steam in the heaters involves an irreversible drop of temperature to the saturation point and that this means an inevitable loss of efficiency.

The author proves that this view is also erroneous and that the relatively slight loss due to the irreversible drop is more than offset by the gain due to the increased temperature range of the regenerative portion of the cycle.

He considers next the case of a turbine plant where the initial absolute pressure of the steam is 500 lb. per sq. in., the temperature 700 deg. fahr., and the condenser vacuum 29 in. Steam for feed heating is extracted at eight stages so chosen as to give approximately equal increments of temperature in the successive heaters, the final temperature being that corresponding to saturation at the initial steam pressure. The complete data are given in a table. The conclusion to which the author arrives is that the thermal efficiency in this case is 0.416, but if no steam were extracted until the expansion had reached the point where the isentropic-expansion line cuts the saturation steam line at 90 lb. pressure and a temperature of 160 deg. cent., the efficiency would be 0.412. Hence by heating the feed to the higher temperature—even though steam extracted at the higher stages for the purpose is superheated—the efficiency is increased, and the author uses this as an argument for showing that there is no fundamental disadvantage in using superheated steam for feed heating.

The article gives some practical suggestions as to the method of calculating the probable effect of heating by means of extracted steam in practice.

Among other things the author demolishes the alleged fallacy that in general superheated steam is not suitable for use as a heating agent in a closed heater, because the rate of heat transmission from superheated steam is low. He claims that the essential point to bear in mind is that in cases where the heating steam cannot escape from the heater, except in the form of condensate, it must give up all its heat content, measured from the condensate temperature, in the heater no matter whether it was wet or superheated initially. For each pound of steam entering the heater, therefore, superheated steam will give up more heat than saturated.

The only effect of a greatly reduced heat transmission would be that with a given heater, superheated steam would not enter at the same rate as saturated steam, since it can only enter at the rate at which it is condensed. But the greater part of the heat exchange takes place at the saturation temperature in both cases, and when the temperature of the surface in contact with the steam is necessarily below this saturation temperature, there is no reason to suppose that there should be any material difference in the total quantities of heat transferred per unit area. It is said that numerous actual tests have confirmed this view.

Where the surfaces in contact with the superheated steam are not necessarily below the saturation temperature, as, for example, in well-covered pipe lines or the valve chests of steam engines, the conditions are different. Here the coefficient of heat transfer becomes of more importance, and hence it is that in such cases the heat loss from superheated steam is less than from saturated. (Thos. B. Morley, D.Sc., in *The Engineer*, vol. 138, no. 3594, Nov. 14, 1924, pp. 544–545, 2 figs., *tA*)

The Steam Accumulator

THE main purpose of the steam accumulator is to equalize fluctuating load, but in the past steam accumulators have not had a storage capacity that could be used for more than to balance peaks of a few minutes' duration. The invention of the Ruths accumulator is said to have advanced matters considerably. (The Ruths accumulator was described in MECHANICAL ENGINEERING, vol. 44, no. 5, May, 1922, p. 323.)

The author believes that accumulators have a very promising field in electric power stations operated with live-steam pressures from 700 to 1400 lb. per sq. in. At these pressures it is necessary

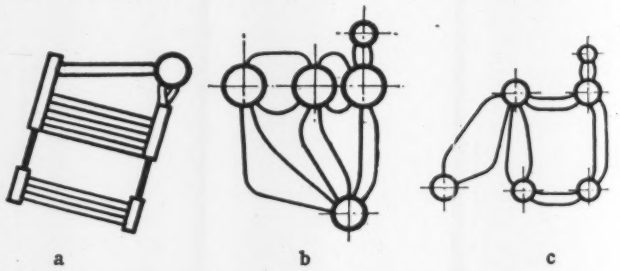


FIG. 6 DIAGRAMS OF SEVERAL TYPES OF BOILER INSTALLATIONS

to design the steam boilers with small steam spaces, because they would otherwise become too heavy and too costly.

At very high pressures, however, the water content of a sectional boiler is not sufficient to take up heavy load and pressure fluctuations of short duration, and it is cheaper in the author's opinion to make the water content of boilers for very high pressure only as large as is necessary for mounting the tubes and for the production of dry steam, and to employ accumulators for the necessary storage capacity, the latter being situated in the low-pressure range.

Vertical tubular boilers of ample water content (*b* or *c*, Fig. 6) are very much more expensive than sectional boilers (type *a*). The reason for this is the high cost of the numerous boiler drums, which, for high pressures, must be made of nickel steel, forged out of one piece, while sectional boilers have only one of these expensive drums. In order to be able to use sectional boilers for reasons of their cheapness and to insure at the same time a

storage capacity of the whole installation, which is at least as high as that obtainable with vertical tubular boilers, an accumulator with auxiliary apparatus should be added. This extra expenditure is only a fraction of the difference in the price of vertical tubular and sectional boilers. The following are the reasons for this considerable saving in capital expenditure: (1) The specific storage capacity of water at 213 lb. per sq. in. is, roughly, seven times as great as at 1400 lb.; (2) The plate thickness is reduced to about one-sixth; (3) The accumulator need not be forged from special, high-quality and expensive steel plates, but can be made up of ordinary riveted mild-steel plates. (Friedrich Münzinger, Consulting Engr. of the A. E. G. of Berlin, in *Combustion*, vol. 11, no. 6, Dec., 1924, pp. 430–435, 11 figs., *g*)

Elastic Capacity of Steam Piping as Affecting Expansion

THE use of steam at higher and higher pressures and temperatures raises some important questions in connection with the ability of piping to take care of its expansion, as, for example, at the temperature of 300 to 350 deg. cent. (572 to 662 deg. fahr.) commonly used in power plants today, the thermal expansion produces an elongation of the order of more than 0.3 per cent (3 mm. per meter). Hitherto reliance has been placed on the so-called expansion joints, but their capacity appears to have been considerably overestimated. The author claims that to take care of the situation created by the use of steam at high temperatures and pressures the piping itself should have sufficient flexibility. He investigated the following factors: (1) Maximum bending moment and determination of the fatigue factor corresponding to the pipe adopted for the piping; (2) reactions at the points of support; and (3) examinations of deformed piping as an element in the study of the support problem. He gives sketches of six designs of piping—some good and some bad—and analyzes the various conditions met with.

Fig. 7 represents a four-branch piping similar to No. 4, Table 1.

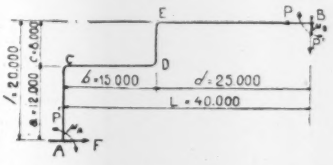
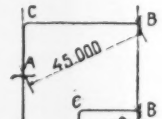
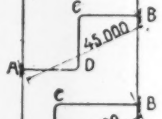
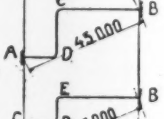
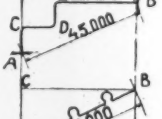
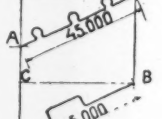
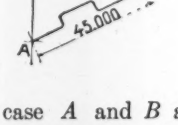


FIG. 7 DIAGRAM OF A FOUR-BRANCH STEAM-PIPING LAYOUT

TABLE 1

No.	Sketches	Fatigue in bending, in kg. per sq. mm.	Reaction P in kg.	Developed length $r = 4\,d$, in meters
1		1.275	7.600	59.742
2		1.000	7.500	59.484
3		0.350	2.150	59.484
4		2.250	20.000	59.226
5		15.000	1000.000	58.730
6		2.070	75.000	51.968

In this case A and B are two flanges to which the piping is attached; d = diameter of the pipe = 150 mm.; T = difference of temperature = 180 deg. cent.; P and P' are the reactions in the two orthogonal directions. It would appear clearly that the maximum bending moment (μ_A) occurs at A; μ_A can be determined as a function of P and P' and of the lengths of the different elements by the following method. Assuming that the position of the flanges A and B is invariable,

$$\int_A^B \frac{Mds}{EI} = 0, \text{ or } \int_A^B Mds = 0$$

where E and I are constants. If now M = bending moment and ds is an infinitesimally small element of the piping, the following holds good:

$$\mu_A = \frac{P(h^2 + 2ab + 2ad + 2cd) - P'(L^2 + 2bc)}{2(L + h)} \quad \ldots\ldots [1]$$

In order to determine the longitudinal and transversal deformations, the author applies formulas for elastic displacement and from those obtains

$$\frac{1}{EI}\left[P\left(\frac{h^3}{3} + a^2b + h^2d\right) - \mu_A\left(\frac{h^2}{2} + ab + hd\right) - \frac{P'}{2}\left(h^2b + hL^2 - a^2b - b^2c\right)\right] = L\alpha T \ldots [2]$$

$$\frac{\mu_A\left(\frac{L^2}{2} + bc\right) + P'\left(\frac{L^3}{3} + b^2c\right) - \frac{P}{2}\left(h^2b + hL^2 - a^2b - b^2c\right)}{EI} = h\alpha T \ldots\ldots [3]$$

From these three formulas the following values in metric units are obtained: $\mu_A = 8.3\,P$, with l = 2.250 kg. per sq. mm. in bending (1 kg. per sq. mm. = 1422 lb. per sq. in.); P (reaction at B) = 20 kg.

In order to determine the deformed shape of the piping, it is sufficient to apply the rules governing bending of straight runs, bearing in mind the partial elongations of the various straight runs.

Longitudinal Direction. The bending at point C is given by the formula

$$f_a = \frac{a^2}{6EI}\left(3\mu_A - P_a\right); \; f_a = 56\,\text{mm.}$$

and the expansion per meter length of piping is 1000 × 180/90,000 = 2 mm. Hence CD expands 15 × 2 = 30 mm. and the displacement of point D is 56 — 30 = 26 mm.; EB expands 25 × 2 = 50 mm. and the displacement of E is 50 mm.

Transverse Direction. Point C is displaced 12 × 2 = 24 mm. and point E is displaced to an extent corresponding to the bending produced at the extreme end of the branch EB and given by the formula

$$f_E = \frac{(3\mu_B - P'd)d^2}{EI}$$

μ_B and P' are determined by Formulas [1], [2] and [3], giving f_E = 83 mm. The branch DE which is 8 m. long expands 16 mm., as a result of which point D is displaced 83 — 16 = 67 mm. On the other hand, analysis of the deformation of $E'B$, the equation of which is

$$y = \frac{(3\mu_B - P'x)x^2}{6EI}$$

shows that there is a salient point defined by its coördinates 23.750 m. and 85 mm. From these data the author traces the shape of the deformed piping, as shown by the dotted lines in Fig. 8. He then proceeds to give in Table 1 the results of a similar study of six different arrangements of piping for solving the same problem, namely, that of connecting two points A and B by piping 150 mm. in diameter (d) and with 180 deg. cent. difference of temperature.

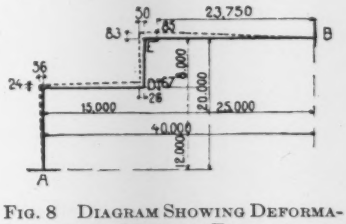


FIG. 8 DIAGRAM SHOWING DEFORMATION UNDER THERMAL EXPANSION OF THE LAYOUT SHOWN IN FIG. 1

The author arrives at the following conclusions:

1 Slight fatigue of the metal as a result of the phenomenon of bending which elements of piping undergo as a result of their deformation.

2 Slight reaction on the joints.

This latter fact is of great importance as it assures conditions necessary for satisfactory maintenance of the joints. What happens when piping does not possess sufficient flexibility? As soon as the piping has been put into service stresses develop tending to compress the joints. Then when the temperature drops, unless the nuts on the flange bolts in the pipe assembly are tightened up, the piping will contract and the joints begin to leak steam. If, on the other hand, the bolts have been kept tight on the flanges at the time of the contraction there will be a tension on the flanges which may attain a very large value, and if for some reason or other steam has been withdrawn from the piping the latter may break.

In certain mechanical constructions there are used what might be called assemblages under tension—for example, the crosshead of an engine with reference to the piston rod. There it is necessary that after the key has been adjusted, tensions should develop at least equal to those produced when the engine is running, as otherwise the transmission of the force will not be free of shock. In the case here considered the assemblage of the pipe flanges should likewise be tensional in character, i.e., the initial stress imposed by the bolting of the joints should be greater than the compressive stress resulting from the expansion of the piping. This desideratum will be attained by giving the piping a shape that will endow it with sufficient flexibility. The author maintains that tight joints depend more on the flexibility of the piping than on the quality of the packing material employed in the joints. He also adds a few words as to the supports. In order to secure all the flexibility that a certain piping layout permits, it is absolutely necessary that the pipe supports be so arranged as not to hinder in any way whatsoever the development of deformations which previous calculation shows to be necessary. Either rollers or sliding-shoe supports may be used, depending on whether the displacement of the piping is longitudinal or compound (i.e., longitudinal and lateral). The original article gives sketches of two such supports. (Henri Carlier, Chief Engr. of the Ressaix Coal Mines, in *Revue Industrielle des Mines*, Series 7, vol. 4, no. 5, Dec. 1, 1924, pp. 276–281, 4 figs., *dpA*)

The Ginabat Surface Condenser

AMONG the elements unfavorably affecting the performance of surface condensers may be named the presence of non-condensable gases and the persistence on the tubes of a film of condensate, both, as is well known, decreasing the output through a reduction of the heat transfer from the steam to the water. It is claimed that the Ginabat design eliminates to a certain extent the unfavorable effects of these two factors.

In the first place the tubes are set as shown in Fig. 9, the result of which is that there is a tendency for the drops of condensate falling from the upper tubes to flow over about a quarter of the surface of the lower tubes rather than over their entire surface.

Fig. 10 shows the arrangement adopted for rows of tubes in a condenser element. Each condenser element consists of only a few rows which are arranged in the condenser in such a manner that the steam flows through the steam pockets formed in between, in the direction with respect to the tubes indicated by the arrows in Fig. 9. The result is that the rear sides of the tubes wetted by the dropping of the condensate lie toward the air pockets, and such air as is liberated in the condenser elements draws away without coming into contact with the condensing surfaces.

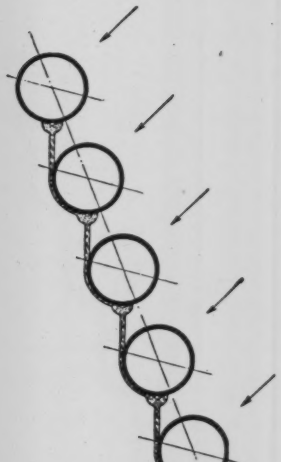


FIG. 9 ARRANGEMENT OF TUBES IN A GINABAT SURFACE CONDENSER

It is claimed that such an arrangement of the individual condenser elements counteracts the harmful influence of air in the condenser and that the air has a chance to affect only a few of the tubes.

Another advantage claimed for this arrangement of condenser elements is that the small depth of the tube banks in the direction of the steam flow reduces materially the resistance offered by the condenser to the steam flow. While in ordinary condensers with numerous rows of tubes located one back of the other the difference between the vacuum at the air outlet and at the steam inlet is often several millimeters of mercury, in this condenser it is very slight. This leads to an improvement in the performance of the air pump and to a further betterment of the vacuum in the steam inlet.

Tests on the coefficients of heat transfer obtained with the Ginabat condenser have confirmed the correctness of the above considerations.

The original article gives data of such tests.

The Ginabat condenser is a French invention and has been applied in a number of central stations in France, among others

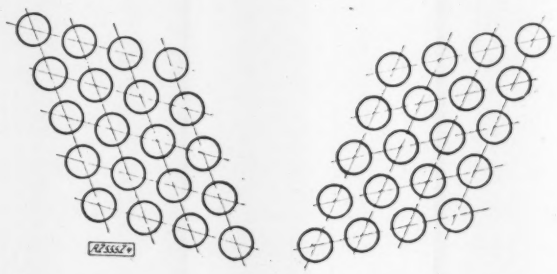


FIG. 10 ARRANGEMENT OF CONDENSER ELEMENTS IN A GINABAT SURFACE CONDENSER

the Gennevilliers Station. (Dr. of Engrg. Ludwig Heuser in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 68, no. 43, Oct. 25, 1924, pp. 1121–1124, 5 figs., *d*)

RAILROAD ENGINEERING

Delaware & Hudson Co. 2-Cylinder Compound Locomotive with High-Pressure Boiler

A SOMEWHAT incomplete description of a new locomotive carrying 350 lb. boiler pressure and developing a tractive effort of 84,300 lb. with a factor of adhesion of 3.54. It has been named the *Horatio Allen* in honor of one of the engineers of the company who was instrumental in bringing over the first steam locomotive from England in the early part of the nineteenth century.

This locomotive has been designed largely to determine what advantages higher steam pressures can give. It is calculated that it will save about one-third of the fuel now used on locomotives of similar capacity.

The locomotive boiler is different from the conventional type, the designer having eliminated the usual stayed type of flat sheet firebox side and crown sheets and water legs and has used instead self-supporting cylindrical containers in line with stationary and marine practice. The firebox contains almost 1200 sq. ft. of heating surface as compared with from 400 to 450 sq. ft. in the largest combined firebox and combustion chambers of the usual locomotive boilers, so that the firebox heating surface represents about 37 per cent of the total evaporation surface as compared with from 5 to 10 per cent attained in ordinary practice. This enables greater advantage to be taken of the radiant heat of combustion for evaporation purposes.

The other principal features are: The physical combination of the cylinders and front frames; removal of dry, branch, and receiver pipes and superheater header from the inside to the outside of the boiler and smokebox; more accessible location of intercepting valve outside of cylinder saddle; application of an interlocking duplex type of low- and high-pressure outside type of main throttle valve; installation of an automatic centrifugal-type saturated-steam separator; an imperforate firebrick baffle wall for the full length and width of the firebox; a secondary superheater for the steam used by the auxiliaries, and a tender-truck booster.

The engine itself is of the consolidation type with 2–8–0 wheel arrangement with compound cylinders, water-tube boiler, and grates designed for burning a mixture of bituminous and anthracite coal. The original article includes a tabulation of weights and dimensions. (*Railway Review*, vol. 75, no. 24, Dec. 13, 1924, pp. 939–943, 1 fig., *d*)

SPECIAL PROCESSES

Making Large-Size Hammer-Welded Pipe

HAMMER-WELDED PIPE is made with diameters ranging from 20 in. to 96 in. and comes in sizes beginning where commercial production of lap-welded pipe ends. It therefore competes mainly with large sizes of cast-iron and riveted steel pipes. Because of its smooth walls and freedom from scale and projections at the joints, it is claimed to be particularly suitable for penstocks, water lines for hydroelectric plants, gas lines, and air and steam conduits. In fact, it is stated that tests have shown the velocity of flow in cast-iron pipe to be 10 per cent less than in hammer-welded pipe.

In a penstock bearing 270 lb., pressure and passing 200 cu. ft. of water per second, it has been calculated on the basis of the velocity of flow that hammer-welded pipe made from $^5/_8$-in. plate, and 48 in. in diameter, would be the equivalent of a 52-in. pipe of $^{13}/_{16}$-in. plate, triple riveted longitudinally and double riveted at the circular seam. The weight of the riveted pipe is about 540 lb. per ft., as against 340 lb. for the welded.

The manufacture of hammer-welded pipe is largely a mechanical process. Most of the pipe produced is 1 in. or less in wall thickness. In the case of thicker pipe the plate is first heated in a specially designed machine to a temperature of 1900 deg. fahr., such a high temperature being necessary as the bending requires at least five minutes and must be completed before the temperature of the steel drops into the brittle range. The bending is done in a set of four rolls, one large upper and three lower ones of smaller diameter. One bottom roll is directly under the upper roll, the others flanking it. When the steel is introduced, it is gripped by the bottom rolls and worked back and forth, the final stage of the operation leaving the plate bent into a cylinder with the edges of the plate overlapping. From the rolls the cylinder goes to the welding machines where a rather unusual process is used.

The anvil of the welding machine is keyed to the front end of the horn, which is a heavy alloy-steel forging about 12 in. deep and reaching clear of its support a sufficient distance to accommodate lengths of pipe of from 21 ft. to 31 ft. The horns actually are much longer, as they rest upon heavy rocker bearings and extend back and are balanced by heavy counterweights. This makes them relatively rigid. A hydraulic piston supports the counterweight at rest and raises or lowers the anvils to give slight manipulation to suit conditions.

The pipe is heated by burners inside and outside. These are mounted directly in front of the horn, the upper one capable of being raised or lowered to prevent fouling the work and to enable the operator to judge of the temperature of the metal being heated. The burners are 20 in. long and heat an area about 2 ft. long by 16 in. wide. In a plate $^3/_8$ in. thick this requires between 30 and 60 sec. to bring it to welding temperature.

An area is heated and then the carriage moves in, bringing the hot section directly over the anvil and below the hammer, swung from a beam directly above. Some of the hammers are air driven, while others are motor powered. Gas and air pipes are carried along the side of the horn and project beyond the anvil, forming the overhanging support of the lower burner.

After welding the pipe is annealed and then conveyed back to the bending rolls and rolled over many times to insure equal curvature in all parts. During this operation water is played on both exterior and interior surfaces to remove scale. Then come the finishing operations. The pipe is mounted in a large lathe having a bed 50 ft. long so that it may accommodate sections made of two lengths welded together circumferentially. Two separate carriages can be set the proper distance apart and the tools then cut off each end simultaneously. The pipes are tested in a huge hydraulic testing machine with 41 ft. reach and 2500 lb. per sq. in. capacity. Tests taken from good pipe, where fracture has actually occurred in the weld, showed an average yield point of 31,390 lb. per sq. in. in the metal and 29,260 lb. in the weld, and an efficiency of the joint, based on the tensile strength, of 92 per cent. Several of the minor operations are described and illustrated in the original article. (Geo. F. Tegan, Resident Editor of *The Iron Age* at Pittsburgh, in *The Iron Age*, vol. 114, no. 20, Nov. 13, 1924, pp. 1263–1268, illsutrated, *d*)

TESTING AND MEASUREMENTS (See also Machine Design: Stress Distribution in Crankshafts)

Duration of Loading and Ball Hardness

IT HAS BEEN known for some time that in the Brinell hardness test the hardness of a metal apparently decreases as the time during which the ball remains under full load increases within certain limits, and there have been numerous tests to determine the influence of the duration of loading. The usual method of carrying out these tests has been to make a more or less considerable number of impression tests under variable duration of loading. The objectionable feature of this process lies in the fact that irregularity of the material under test may be such as to conceal the influence of the factor of duration of loading, and reliance for the determination of this latter has then to be placed on the average values obtained from the experiment. In order to eliminate as much as possible this factor, the following method was proposed: The test is made under a short duration of loading. The impression is then measured, when a ball is placed in the old impression and the same pressure applied for a given length of time, after which the impression is measured again. This method has also certain disadvantages and because of this an entirely different process has been evolved in the experimental laboratories of the Krupp Company at Essen, which it is claimed is free from the disadvantages of the former processes.

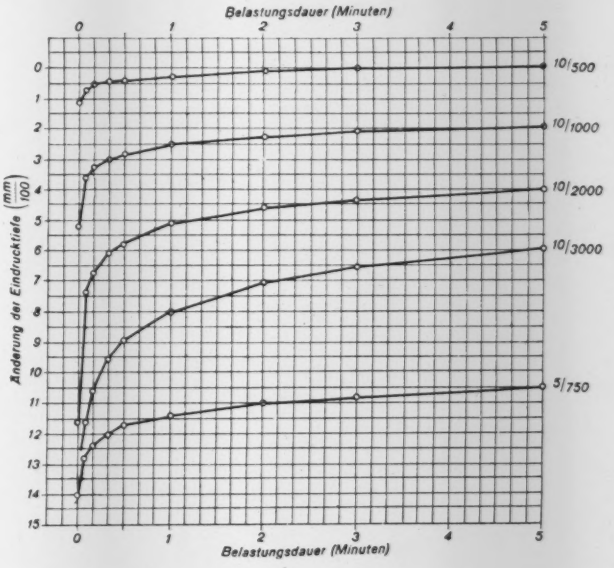


FIG. 11 BRINELL HARDNESS TESTS ON SOFT IRON

(Ordinates: Variations in depth of impression in $\frac{mm}{100}$; abscissas: durations of maintenance of load in minutes.)

In the Krupp process the variation of the depth of impression as a function of the duration of loading is determined by measuring, within a single test and without withdrawing the pressure, the depths of impressions at given time intervals. The Martens mirror device is used for this purpose, and the original article describes both the methods of carrying out the tests and the results obtained. Fig. 11 is a good example of the latter. It shows a series of curves secured on soft iron having a Brinell hardness of about 80. These curves show that even after a pressure has been applied for five minutes the state of equilibrium has not been reached. The reduction of the load to $P = 5\ D^2$ (where P is in kilograms and the ball diameter D is in millimeters) did not help to bring about the state of equilibrium much faster, as is shown by another set of curves in the original article not reproduced here. Another group of curves in the original paper for two kinds of hard steel show that with that material the state of equilibrium is established after one minute of loading, but in the case of very soft steel, even after five minutes, the state of equilibrium is not yet attained. The same tests have indicated that the variation due to increased duration of loading in the case of such materials as steel, both soft and hard, does not exceed, say, 3 per cent, so that Brinell

tests with a duration of loading of 10 sec. give results within 3 per cent of those obtained with the loading maintained for 5 min. For soft iron the same results are obtained with a duration of loading of 20 sec. but for metals like zinc the duration of loading must be increased to two or three minutes, and it must be borne in mind that these metals do not reach their state of equilibrium even after a loading of five minutes. Tests on copper have shown that with this metal variations of loading have no very appreciable effect. (Richard Mailänder in *Kruppsche Monatshefte*, vol. 5, Oct., 1924, pp. 209–213, 14 figs., *e*)

STEAM ENGINEERING (See Motor-Car Engineering: British Steam Wagon)

THERMODYNAMICS (See also Varia: German Law Concerning Temperature Scales and Heat Units)

VARIA

German Law Concerning Temperature Scales and Heat Units

A NEW LAW was passed August 7, 1924. In accordance with the first paragraph thereof the thermodynamic scale was recognized as the legal scale of temperatures with the provision that the normal melting temperature of ice be 0 deg. and the normal boiling temperature of water be designated as 100 deg., the National Physico-Technical Bureau being authorized to determine and publish these scales of temperature.

This definition is somewhat different from the common conception of the celsius or centigrade scale. The original way the centigrade scale was laid out was to mark on the capillary tube of a mercury thermometer the melting point of ice and the boiling point of water and to divide the distance between them into 100 equal parts. This gave a temperature scale which apart from its other defects was quite difficult to duplicate, because the expansions of the mercury determining the values of the degrees depend quite materially on the kind of glass used for the thermometer tube. This led to the use of gas thermometers as in these the expansion of the vessel is insignificant as compared with the expansion of the contents, the expansion of the gas at constant pressure or the increase of pressure at constant volume being accepted as a measure of temperature. Even here, however, slight divergences occurred, depending on the character of the gas, particularly in the measurement of very high or very low temperatures. These variations were reduced by extrapolation to very small pressures and by the use of monatomic gases, so that finally scientists arrived at a conception of an "ideal" or "perfect" gas, in the case of which variations of state occur in accordance with the simple law of gases:

$$pv = RT = R\left(\frac{1}{a} + t\right) \qquad [1]$$

The temperature scale built up from this equation is called the "thermodynamic" scale, and the name given to it is due to the fact that this scale was worked out by purely thermodynamic processes, in that there are here measured the heat content W taken up at the higher temperature T_1 and the part of this heat M converted into mechanical work, these being measured in a Carnot cyclic process consisting of two isothermal and two adiabatic variations of state. If the "low temperature" of the process is the temperature of melting ice T_0, then

$$\frac{M}{W} = \frac{T_1 - T_0}{T_1}$$

or

$$T_1 = \frac{T_0}{1 - \frac{M}{W}}$$

which serves to determine the scale of temperatures. In practice the scale cannot be represented in this way, but the thermodynamic scale defined purely by a cyclic process independent of the working material has the enormous advantage in that even at the highest temperatures at which the gas thermometry no longer holds it remains true, and can also be used as a foundation for the measurement of radiation. The next question is how the scale of temperatures is actually established. If we measure, for example, at constant pressures the volumes v_0 and v_{100} of a piece of iron at the normal temperature of melting ice and at the normal temperature of boiling water, which temperatures may be designed as $t = 0$ and $t = 100$, we get from Equation [1]

$$\frac{v_{100}}{v_0} = \frac{\frac{1}{a} + 100}{\frac{1}{a}}$$

hence

$$\frac{1}{a} = \frac{100 v_0}{v_{100} - v_0} \qquad [2]$$

and from Equations [1] and [2] an expression may be obtained for any other temperature t:

$$\frac{v}{v_0} = \frac{\frac{1}{a} + t}{\frac{a}{1}}$$

or

$$v = v_0 \frac{\frac{100\, v_0}{v_{100} - v_0} + t}{\frac{100\, v_0}{v_{100} - v_0}} = v_0 + \frac{v_{100} - v_0}{100}\, t \qquad [3]$$

It should be noticed, however, that Equation [3] strictly holds good only for $p = 0$. Since, however, it is difficult to work with extremely small pressures, in gas thermometry work is carried on at convenient pressures and extrapolated to $p = 0$. If this is done Equation [3] will represent the legal scale of temperatures just adopted in Germany, and since measurements of gas temperatures required for this purpose are difficult to make and possible only where special apparatus is available, the National Physico-Technical Bureau (an organization somewhat similar to the U. S. Bureau of Standards in this country) has been authorized to take care of that.

According to the second paragraph of the new law the legal units for the measurement of quantity of heat are the kilocalorie (kcal.) and the kilowatt-hour (kWh.), kcal. being defined as the quantity of heat by which one kilogram of water at atmospheric pressure is heated from 14.5 to 15.5 deg. cent. The kWh. is equal to 860 kcal.

The law provides that in business intercourse all temperatures and quantities of heat shall be measured by their legal units and the National Physico-Technical Bureau is authorized to determine the tolerances of measuring apparatus, the use of apparatus having errors in excess of permitted tolerances being prohibited.

The article gives some data as to how certain temperatures were determined. For this purpose the Bureau has published officially the temperature of certain reference points (melting points, boiling points, etc. of various substances) determined by gas thermometry, and has also given interpolation formulas by means of which any temperature may be determined by measurement with electric thermometers, providing these latter have been calibrated to the standard points of temperature reference. Standard instructions are also given for the methods of measuring temperatures within the various ranges, and, e.g., that between the melting point of ice and solidification of antimony is measured in accordance with a certain formula by the resistance of a pure platinum wire. (Max Jakob in a communication from the National Physico-Technical Bureau published in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 68, no. 45, Nov. 8, 1924, pp. 1176–1178, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code for Reciprocating Steam-Driven Displacement Pumps

Republication of Code after Review and Revision by a Reorganized Committee

THE Main Committee on Power Test Codes takes pleasure in presenting to the members of the Society again the Test Code for Reciprocating Steam-Driven Displacement Pumps for criticism and comment. The Individual Committee which developed this draft of the code consists of Messrs. R. D. Hall, Chairman, C. H. Anderson, E. H. Brown, J. N. Chester, J. E. Gibson, G. L. Kollberg, M. B. MacNeille, D. W. Mead, and L. A. Quayle. It is believed that in its present form this code meets the needs of all groups which from time to time have a part in the making of acceptance tests of this type of apparatus.

In 1918 the Committee on Power Test Codes was organized by the Council of the A.S.M.E. to revise and enlarge the Power Test Codes of the Society published in 1915. This committee consists of a Main Committee of twenty-five members under the chairmanship of Fred R. Low, and nineteen Individual Committees of specialists who are drafting test codes for the various prime movers and the other auxiliary apparatus which constitute power-plant equipment.

The Individual Committee, the Main Committee, and the Society will welcome suggestions for corrections or additions to this draft from those who are especially interested in the manufacture, use, and testing of Reciprocating Displacement Pumps. These comments should be addressed to the Chairman of the Committee in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

1 The Code for Reciprocating Steam-Driven Displacement Pumps applies to tests for determining the performance of the pump and engine, including reheaters, heaters and jackets, if any, and jacket pumps, circulating pumps, condensate pumps and vacuum pumps, which are concerned in their operation.

NOTE: If any of the auxiliaries are independently driven, their efficiency may be determined separately from the main unit. For tests of pumping machinery and boiler plant combined, reference should be made to the Code for Complete Steam Power Plants.

Object

2 In accordance with the Code on General Instructions, the object of the test should be determined and recorded. If the object relates to the fulfilment of a contract guarantee, an agreement should be made between the interested parties concerning all matters about which dispute may arise, as noted in the Code on General Instructions, and the points agreed upon should be stated in the Report of the Test.

Measurements

3 The fundamental measurements for a duty trial of a reciprocating steam pumping engine are:

(*a*) Amount of water pumped, in pounds
(*b*) Average total dynamic head, in feet
(*c*) Amount of steam supplied, in pounds; or the amount of heat supplied, in British thermal units (B.t.u.).

The standard units for volume, head, and power are:

(*a*) The standard unit for volume shall be the U. S. gallon or the cubic foot. The gallon unit shall be expressed in million gallons per day (m.g.d.) of 24 hours. The cubic-foot unit if used shall be expressed in cubic feet per second. The standard U. S. gallon contains 231 cu. in.
(*b*) For temperatures not exceeding 85 deg. fahr. the specific gravity of water may be taken as unity. (At 85 deg. the specific gravity equals 0.9957.)
(*c*) 7.48 gallons is equal to 1 cubic foot, and 448.8 gallons per minute is equal to 1 cubic foot a second. 695 gallons per minute is equal to one million gallons per day of 24 hours.
(*d*) The unit for measuring head shall be the foot. The relation between pounds per square inch and feet head is 2.31 ft. = 1 lb. per sq. in. when the specific gravity of the liquid is unity.
(*e*) In reading gages calibrated in pounds per square inch when other than water is handled, it is necessary to divide the reading in pounds by the specific gravity and multiply by 2.31. Example: 100 lb. pressure on brine of 1.25 gravity = 185 ft. head, or on oil of 0.85 gravity, 272 ft.

Instruments and Apparatus

4 The instruments and apparatus required for a performance test of a steam-driven reciprocating displacement pump include:

(*a*) Tanks and platform scales for weighing water
(*b*) Graduated scales attached to the water glasses of the boiler, if the feedwater is measured
(*c*) Pressure gages, vacuum gages; and thermometers provided with suitable wells
(*d*) Steam calorimeter
(*e*) Barometer
(*f*) Revolution counter or other accurate speed-measuring device
(*g*) Indicators
(*h*) A planimeter
(*i*) A deadweight gage tester.

Directions regarding the application, use, and calibration of the instruments and apparatus noted and statements as to their accuracy are given in the Code on Instruments and Apparatus.

The gage on the discharge main should be attached near the pump discharge nozzle, and that on the suction main near the suction nozzle. These gages should be attached at an angle of 90 deg. to the direction of flow. The gage pipes should be provided with valves at the gages and pet-cock air vents.

When a suction or discharge surface condenser is in use as part of the unit under test, the water-head readings should be made outside of and beyond the condenser so that the loss of head through the surface condenser will be charged against the main unit.

Preparations

5 The Code on General Instructions should be studied. The dimensions of the pumps should be determined and recorded. Note should also be taken of the physical conditions not only of the pumping machinery but of all parts of the plant concerned.

6 *Leakage Test of Pump.* The tightness of the suction and discharge valves (and the plunger packing, if the pump is of the inside-packed construction) should be ascertained by applying the specified discharge pressure on them and observing the leakage by removing a handhole or manhole cover on the suction side of the part being tested. If essential to the object in view, the valves should be made tight; the plunger packing should leak only enough to insure that the friction of the packing on the plunger is not excessive. In the case of direct-acting pumps with inside-packed plungers the amount of leakage may be estimated by closing the discharge valve and running the pump just fast enough to maintain the normal discharge pressure. If sufficient leakage is found to affect the capacity materially, the conditions should be corrected before proceeding with the test work.

7 *Steam Rate.* The steam rate of the engine should be determined by measuring the condensate from the surface condenser, if that type of condenser is in use. If the condenser leaks, the defects causing such leakage should be remedied before test. The amount of condensation from jackets, receivers, and reheaters, as well as the steam used by the auxiliaries concerned, if not included in the condensate from the condenser, should be added thereto. (See Note, Par. 1.) If a surface condenser is not available, the steam supplied to the engine should be determined by feedwater tests, which require the measurement of the water fed to the boiler. The water from separators and drips on the main steam line, the steam used for other equipment not a part of the engine under test, and the water and steam which escape by leakage from the boiler and piping, must also be measured, and these quantities deducted from the total quantity of feedwater.

8 *Measurement of Water Pumped.* The quantity of water pumped should be determined by computing the actual plunger displacement in U. S. gallons or cubic feet. It is advisable, where apparatus is available, to check the total pumpage by the use of venturi tubes, pitometer, weir, calibrated orifice, etc. or by means of the use of a reservoir, proper precautions being taken to insure

reliable results in accordance with the directions of the Code on Instruments and Apparatus. In direct-acting pumps, the actual stroke of each plunger must be determined by the use of graduated stroke scales.

Operating Conditions

9 The operating conditions should conform to the object of the test and these should prevail throughout the trial, as pointed out in the Code on General Instructions. If an air pump is used to remove air which enters the suction pipe in the supply system of the pumping engine, such a pump is not to be considered a part of the engine equipment so far as it concerns the test.

Starting and Stopping

10 The engine and appurtenances should be first thoroughly heated and run under the prescribed conditions until uniformity is secured. When surface-condenser measurement is used, the duration of the test should be not less than eight (8) hours. Where the steam consumption is determined by measuring the feedwater to the boiler, the duration of the test should be not less than ten (10) hours.

11 When a surface condenser is used, the test should start by commencing to weigh or measure the condensate and any other quantities of steam consumption involved, at the same time beginning the observations and other necessary test work. At the end of the allotted time the test is stopped by discontinuing the measurements and observations. When feedwater measurements are employed, the test should be started by carefully observing the steam pressure and water level in the boiler, and the level in the feed tank if measuring tanks are used, at the same time beginning the water measurements and taking up the routine work of the test. Toward the end of the prescribed time, when the water levels, steam pressure, and conditions of fire and draft are as near as practicable to the same points as at the start, the observations should be discontinued. If there are differences in the water levels, corrections must be applied to the water measurements.

Records

12 The general data should be recorded as pointed out in the Code on General Instructions. Instruments should be read at intervals not greater than fifteen minutes, and if complete test data are required, indicator cards should be taken from each end of each cylinder once each hour when the conditions are uniform, and oftener when there is much variation. The log should contain the record of the readings of all gages, thermometers, calorimeters, speed indicator, and all other instruments. If desirable, representative steam-pipe diagrams may be taken with an indicator applied near the throttle valve and operated by connection to the reducing motion of the cylinder indicators.

13 A typical set of indicator cards should be selected from the whole number taken, and these should be embodied in the record. The specimen cards selected should be such as to show the average conditions of pressure and cut-off. If steam-pipe diagrams are obtained, specimens of these should also be placed in the record.

14 *Throttle Pressure.* The throttle pressure, or the average pressure in the steam pipe just before the throttle, is that shown by a calibrated steam gage attached to the steam pipe $1\frac{1}{2}$ to 2 diameters from the throttle.

Calculation of Results

15 *Steam Rate.* State in the report of the test the actual steam rate as measured. State also in the report of the test the total amount of "estimated steam" supplied, as corrected for pressure, quality, or vacuum, in accordance with the correction factor based as far as possible on data obtained from the engine under test and as previously agreed upon by the interested parties in accordance with the Code on General Instructions and the Code on Definitions and Values.

16 *Heat Supplied.* The heat supplied to a steam engine is the total heat content of the steam entering the engine, less the total heat returnable from engine to boiler. (Code on Definitions and Values, Par. 134.)

The heat returnable is the sum of the total heat returned from the various sources as follows:

a The heat returned in the condensate from the air pump; i.e., the product of the heat of the liquid per pound, above 32 deg. fahr., corresponding to its temperature; and the total weight of such condensate.

b The heat returned in any feedwater heater using exhaust steam or steam from the working charge in the engine.

c The heat returned in high-temperature jacket and other drain water.

17 *Thermal Efficiency.* See Code on Definitions and Values, Par. 136.

18 *Rankine-Steam-Cycle Efficiency.* See Code on Definitions and Values, Par. 145.

19 *Engine Efficiency.* See Code on Definitions and Values, Par. 143.

20 *Head.* The total dynamic head is determined from two elements, viz., the "discharge head," which is the pressure in pounds per square inch expressed in feet head in the discharge main referred to the center line of the pump cylinders (or other datum line as may be determined on), and the "suction lift" or "suction head," which is the vacuum or head in the suction main referred to the same datum line. When the suction main is under a vacuum the head is found by adding the "suction lift" to the "discharge head," both expressed in feet. When the suction main is under pressure the head is found by subtracting the "suction head" from the "discharge head," both expressed in feet.

21 *Discharge Head.* The discharge head is found by adding to the head in feet shown by the gage connected to the discharge main the vertical distance in feet between the center of the gage (if of the Bourdon spring type) or the lower surface of the mercury (if of the mercury type) above the center line of the pump cylinders (or other datum determined on). Should the gage be located below the datum line, this distance is to be subtracted instead of added.

22 *Suction Lift.* The suction lift is found by adding to the reading in feet shown by the gage connected to the suction main, the vertical distance in feet between the datum line noted and the point where the gage pipe connects to the main. Should the point of connection of the gage be located above the datum line, this distance is to be subtracted instead of added.

23 *Suction Head.* The suction head, which obtains in cases where the suction pipe is under pressure, is found by subtracting the vertical distance in feet between the datum line and the center of the gage on the suction main (if of the Bourdon spring type) or the lower surface of the mercury (if of the mercury type) from the pressure in feet shown by the suction gage.

24 *Leakage of Pump.* The percentage of leakage in a reciprocating pump is found by dividing the quantity of leakage during the test, as computed from the rate of leakage determined on the leakage trial, by the plunger displacement during the test, and multiplying the quotient by 100.

25 *Capacity.* The capacity by displacement, in cubic feet per 24 hours, is found by multiplying the net or effective area in square feet of all the plungers by the length of the stroke in feet, the number of discharge strokes per minute, and the constant 1440. The equivalent capacity in U. S. gallons per 24 hours is found by multiplying the capacity in cubic feet as determined above by the constant 7.48.

26 *Water Horsepower.* The water horsepower is found by multiplying the weight of water pumped, in pounds per hour, by the average total dynamic head in feet, and dividing the product by 1,980,000.

27 *Engine Indicated Horsepower.* The average engine indicated horsepower for the entire test is found by dividing the average water horsepower as computed in Par. 26 by the average combined hydraulic and mechanical efficiency of the entire unit as computed in Par. 30.

28 *Duty per 1000 Lb. of Steam.* The duty in foot-pounds of work done per 1000 pounds of steam is found by multiplying the number of pounds of water pumped during the test by the average total dynamic head in feet, dividing the product by the number of pounds of steam supplied during the test, and multiplying the quotient by 1000.

29 *Duty per 1,000,000 B.t.u.* The duty in foot-pounds of work done per 1,000,000 B.t.u. is found by multiplying the number of pounds of water pumped during the test by the average total dy-

namic head in feet, dividing the product by the number of B.t.u. supplied, and multiplying the quotient by 1,000,000.

30 *Friction and Mechanical Efficiencies.* The average combined hydraulic and mechanical efficiency of the entire unit is 100 times the average of the ratios of instantaneous water horsepower to engine indicated horsepower shown by all normal indicator cards taken during the test.

DATA AND RESULTS

31 The data and results of the test should be reported in accordance with the form given herewith. Unless otherwise indicated, the items should be the averages of all observations.

NOTE: Add lines for desired data not already provided; omit lines for data not required.

DATA AND RESULTS OF RECIPROCATING STEAM-DRIVEN DISPLACEMENT PUMPS

(A.S.M.E., TEST CODES OF 1923.)

GENERAL INFORMATION

(1) Date of test
(2) Location
(3) Owner
(4) Builder
(5) Test conducted by
(6) Object of test
(7) Duration of test

DESCRIPTION AND GENERAL DIMENSIONS

(8) Type of unit
(9) Number of steam cylinders
(10) Diameter of steam cylinders { h.p. ..... in. / i.p. ..... in. / l.p. ..... in.
(11) Diameter of steam piston rods ..... in.
(12) Stroke of steam pistons ..... in.
(13) Plungers, number
(14) Single or double acting
(15) Inside or outside packed
(16) Diameter of plungers ..... in.
(17) Stroke of plungers ..... in.
(18) Diameter of plunger rods (if any) ..... in.
(19) Net area of each plunger ..... sq. ft.
(20) Type of condenser
(21) Location of condenser
(22) Cooling surface in condenser ..... sq. ft.
(23) Type and size of condenser pumps
(24) Type and size of any exhaust or receiver, feedwater heaters, steam reheaters and jacket pumps or other auxiliaries a part of the unit

TEST DATA AND RESULTS

Pressures

(25) Steam pressure at throttle ..... lb. per sq. in.
(26) First receiver pressure ..... lb. per sq. in.
(27) Second receiver pressure ..... lb. per sq. in.
(28) H.p. jacket ..... lb. per sq. in.
(29) I.p. jacket ..... lb. per sq. in.
(30) L.p. jacket ..... lb. per sq. in.
(31) Barometer ..... inches of mercury ..... lb. per sq. in.
(32) Corresponding absolute pressure ..... lb. per sq. in.
(33) Vacuum in exhaust pipe near l.p. cylinder ..... inches of mercury ..... lb. per sq. in.
(34) Corresponding absolute pressure near l.p. cyl. ..... lb. per sq. in.
(35) Vacuum in condenser ..... inches of mercury ..... lb. per sq. in.
(36) Corresponding absolute pressure in condenser ..... lb. per sq. in.

Temperatures

(37) Steam at throttle valve ..... deg. fahr.
(38) Exhaust steam ..... deg. fahr.
(39) Water pumped ..... deg. fahr.
(40) Condensate leaving surface condenser ..... deg. fahr.
(41) Condensate or feedwater entering feedwater heaters ..... deg. fahr.
(42) Condensate or feedwater leaving feedwater heaters ..... deg. fahr.
(43) Temperature rise in feedwater heaters ..... deg. fahr.
(44) Condensate from jackets ..... deg. fahr.
(45) Condensate leaving 1st receiver ..... deg. fahr.
(46) Condensate leaving 2nd receiver ..... deg. fahr.
(47) Condensate from other drains ..... deg. fahr.
(48) Engine-room air ..... deg. fahr.
(49) External air ..... deg. fahr.

Total Dynamic Head

(50) Discharge pressure by gage ..... lb. per sq. in.
(51) Equivalent discharge head ..... ft. of water
(52) Vacuum or pressure shown by gage on suction main ..... ft. of water
(53) Discharge head referred to datum line ..... ft. of water
(54) Suction head or suction vacuum referred to datum line ..... ft. of water
(55) Total dynamic head pumped against ..... ft. of water
(56) Actual suction lift (if any) measured to highest point of discharge valve deck ..... ft. of water

Quality of Steam near Throttle

(57) Dryness factor of steam ..... per cent
(58) Superheat in steam (if any) ..... deg. fahr.

Total Steam Quantities

(59) Total steam as measured supplied to engine and the auxiliaries concerned in its operation as specified ..... lb.
(60) Correction factor conforming to conditions agreed upon ..... per cent
(61) Total "estimated steam" supplied conforming to conditions agreed upon ..... lb.

Total Pump Quantities

(62) Total quantity of water pumped by plunger displacement ..... U. S. gal. or cu. ft.
(63) Equivalent total weight of water pumped ..... lb.
(64) Total quantity of water pumped as shown by other means of measurement ..... U. S. gal. or cu. ft.

Hourly Steam Quantities

(65) Steam, as measured, supplied per hour ..... lb.
(66) "Estimated steam" supplied per hour ..... lb.

Hourly Pump Quantities

(67) Quantity of water pumped per hour by plunger displacemen. ..... U. S. gal. or cu. ft.
(68) Equivalent weight of water pumped per hour ..... lb.
(69) Quantity of water pumped per hour as shown by other means of measurement ..... U. S. gal. or cu. ft.
(70) Slip in percentage of plunger displacement ..... per cent

Heat Supplied (Based on steam supplied, as measured, Item 59)

(71) Total heat per pound of steam at throttle ..... B.t.u.
(72) Total heat in steam supplied ..... B.t.u.
(73) Total heat returnable from engine to boiler ..... B.t.u.
(74) Net heat supplied ..... B.t.u.
(75) Net total heat supplied per hour ..... B.t.u.

Heat Supplied (Based on total "estimated steam," Item 61)

(76) Total heat per pound of steam at throttle ..... B.t.u.
(77) Total heat in steam supplied ..... B.t.u.
(78) Total heat returnable from engine to boiler ..... B.t.u.
(79) Net heat supplied ..... B.t.u.
(80) Net total heat supplied per hour ..... B.t.u.

Speed

(81) Total number of revolutions
(82) Total number of single strokes
(83) Actual length of stroke, if direct-acting ..... ft.
(84) Revolutions per minute ..... r.p.m.
(85) Single strokes per minute ..... Str. per min.
(86) Piston and plunger speed per minute ..... ft. per min.

Power

(87) Total work done during test ..... ft-lb.
(88) Water horsepower ..... w.hp.
(89) Combined hydraulic and mechanical efficiency ..... per cent
(90) Indicated steam horsepower ..... i.hp.
(91) Mean effective pressure (referred to l.p. cylinder if multiple-expansion engine) ..... lb. per sq. in.
(92) Indicated water horsepower ..... i.w.hp.

Economy Results (Based on steam supplied as measured, Item 65)

(93) Steam supplied per i.hp-hr. ..... lb.
(94) Heat supplied per i.hp-hr. ..... B.t.u.
(95) Heat supplied per water hp-hr. ..... B.t.u.

Economy Results (Based on "estimated steam," [1] Item 66)

(96) Steam supplied per i.hp-hr. ..... lb.
(97) Heat supplied per i.hp-hr. ..... B.t.u.
(98) Heat supplied per water hp-hr. ..... B.t.u.

Efficiency Results

(99) Thermal efficiency (referred to i.hp.) based on steam as measured [2545 ÷ Item 94] ..... per cent
(100) Thermal efficiency (referred to i.hp.) based on "estimated steam"[1] [2545 ÷ Item 97] ..... per cent

Duty

(101) Duty per 1000 lb. of steam as measured ..... ft-lb.
(102)[1] Duty per 1000 lb. of "estimated steam" ..... ft-lb.
(103) Duty per 1,000,000 B.t.u. based on steam supplied, as measured ..... ft-lb.
(104)[1] Duty per 1,000,000 B.t.u. based on "estimated steam" ..... ft-lb.

[1] The correction factor used shall be stated in percentage, and the basis and method of determining it described.

DUTY TRIALS AND TESTS OF RECIPROCATING DISPLACEMENT PUMPS DRIVEN BY PRIME MOVERS OTHER THAN RECIPROCATING STEAM ENGINES

32 The rules given above apply to all reciprocating water ends of pumps regardless of the type of driving apparatus.

33 For rules governing the driving machine, see Code which applies to such machine (as an oil engine, gas engine, water wheel, etc.)

34 In cases in which the pump is driven by an electric motor, the characteristics and efficiency of the motor, and the power input to the motor should be obtained and used in accordance with the rules of the American Institute of Electrical Engineers.

35 The form of the tabulation of the test results for other than steam-driven reciprocating pumps will be dependent on the object of the test and will, in general, be a combination of the parts of the Summary which refer to the pump and the form recommended in the Code applying to the driving machine.

Correspondence

CONTRIBUTIONS to the Correspondence Department of "Mechanical Engineering" are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on articles or policies of the Society in Research and Standardization.

Dynamic Stresses in Rotating Gear Pinions

TO THE EDITOR:

The writer wishes to comment on Paul Heymans' paper entitled Mathematical Theory of Dynamic Stresses in Rotating Gear Pinions, published in the October, 1924, issue of MECHANICAL ENGINEERING.

The writer agrees with the author of this paper that vibrations and stresses corresponding thereto occur, even though the gearing is perfect and the tangential force constant. However, he believes that the author has not proved his position; nor is such a proof possible with the model of a pinion used by him in the derivation of his equations.

This model evidently is a disk, perfectly rigid, mounted on a massless shaft, whose torsional rigidity is equal to that of the actual pinion. With this model, Equations [1] to and including [8a] lead to the well-known expressions for the torsional vibrations of a system of one degree of freedom. Attention is called to the fact that Equations [5] to [8a] for forced torsional vibrations apply only in the special case when the Fourier series for the impressed force has nothing but cosine components. With reference to the problem of the perfect pinion the author attempts to show the presence of vibrations arising solely from the cyclic engagement of the teeth of the pinion. Obviously, all forces which cause vibrations irrespective of the perfection of shape and spacing of the teeth must be excluded.

Thus the author correctly proposes to consider in the present problem only a constant tangential force. However to specify the problem more fully it must be understood:

1 That the action of the constant force is also continuous, so that, irrespective of what tooth may be engaged by the force at any given time, there is no instant wherein the pinion is without force, and

2 That when two teeth of the pinion happen to be in simultaneous engagement with the co-acting gear, the algebraic sum of the tangential forces to which these teeth are subject is constant and equal in value to the constant tangential force when only one tooth is engaged. Without this assumption we should have a variable torque and vibrations irrespective of the perfection of the gearing.

The above being so, we have simple means to test the accuracy of the author's formula (near top of right column, page 584) for the perfect pinion and with constant tangential force. For therein the tangential force at any instant of time evidently is:

$$\sum_{\lambda}^{1.2\ldots m}\sum_{\nu}^{1.2\ldots m} A_{\nu\lambda}\cos(p_{\nu\lambda}t)$$

which according to hypothesis should be constant.

It is difficult to see how far a summation of m forces, each a different function of the time and each composed of m harmonic components, can be constant for any desired instant of time.

Why should there be in the present problem m different forces, each with its own complement of terms in its Fourier series?

Is it not a fact that when the force on tooth No. 1 is expressed by $f(t)$, then the force on tooth No. 2 will be $f(t-\Delta)$, the force on tooth No. 3 $f(t-2\Delta)$, etc. wherein Δ is the constant time interval between the engagement of one tooth and the succeeding one?

In other words, is not in the present problem the Fourier series for the forces on teeth Nos. 1, 2, 3, etc. term for term the same (the same amplitude and the same frequency) except for the phase differences corresponding to Δ?

If so, let us assume that the pinion makes one revolution in one second which makes the fundamental frequency of the forces in the Fourier series equal to 1. Let there further be n teeth, so that per second there will be n engagements, which makes the time interval between successive engagements $\Delta = 1/n$. Then the force on teeth Nos. 1, 2, 3, etc. may be expressed as follows:

$$1\,f(t) = A + B\sin(2\pi t + \alpha) + C\sin(4\pi t + \beta) + \text{- - - - - -}$$

$$2{:}\,f\left(t-\frac{1}{n}\right) = A + B\sin\left\{2\pi\left(t-\frac{1}{n}\right)+\alpha\right\} + C\sin\left\{4\pi\left(t-\frac{1}{n}\right)+\beta\right\} + \text{- - -}$$

$$3{:}\,f\left(t-\frac{2}{n}\right) = A + B\sin\left\{2\pi\left(t-\frac{2}{n}\right)+\alpha\right\} + C\sin\left\{4\pi\left(t-\frac{2}{n}\right)+\beta\right\} + \text{- - -}$$

$$k{:}\,f\left(t-\frac{k-1}{n}\right) = A + B\sin\left\{2\pi\left(t-\frac{k-1}{n}\right)+\alpha\right\} + C\sin\left\{4\pi\left(t-\frac{k-1}{n}\right)+\beta\right\} + \text{- - -}$$

wherein A, B, α, and β are constants.

Now the tangential force at any instant of time is

$$f(t) + f\left(t-\frac{1}{n}\right) + f\left(t-\frac{2}{n}\right) + \text{- -} f\left(t-\frac{k-1}{n}\right) + \text{- - -}$$

which according to the hypothesis must be constant. This requires that

$$\sum_{k}^{1..n}\sin\left\{2\pi\left(t-\frac{k-1}{n}\right)+\alpha\right\} = 0;\quad \sum_{k}^{1..n}\sin\left\{4\pi\left(t-\frac{k-1}{n}\right)+\beta\right\} = 0;\ \text{etc.} \qquad [1]$$

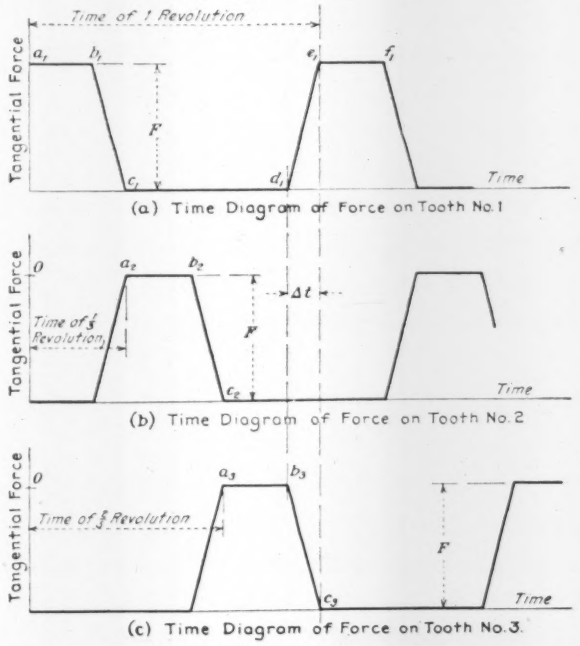
which in turn demands that all terms with frequencies $2n\pi$ and multiples thereof vanish.

If we now determine the torsional vibrations of the author's disk model for the simultaneous action of the forces with circular frequency 2π, we shall find by virtue of the relations [1] the result to be zero. The case is similar for the forces with circular frequency 4π, 6π, etc. In other words, contrary to the author's conclusion, no vibrations will be excited notwithstanding the cyclic engagement of

the teeth. However, the fact that the author is not entitled to deduce the existence of vibrations in a perfect pinion with constant tangential force from his mathematical analysis, can be demonstrated much simpler as follows:

Let Fig. 1(*a*) of the present discussion be the time diagram of the tangential force on tooth No. 1, and let the number of teeth in the pinion be assumed to be only 3 for the sake of brevity.

In the time from a_1 to b_1 tooth No. 1 is alone in engagement with the co-acting gear and subject to the constant tangential force F. At the instant b_1 simultaneous engagement of teeth Nos. 1 and 2 with the gear begins, the tangential force on tooth No. 1 decreases and becomes zero at c_1, at which instant No. 1 is entirely out of engagement and remains so until d_1 at this instant engagement of tooth No. 1 begins again; the tangential force increases until at e_1



(a) Time Diagram of Force on Tooth No. 1

(b) Time Diagram of Force on Tooth No. 2

(c) Time Diagram of Force on Tooth No. 3

FIG. 1 TIME DIAGRAMS OF FORCES ON TEETH

tooth No. 1 is again in sole engagement with the gear and the force has reached its full value F. The time from a_1 to e_1 is the time of one complete revolution and the cycle of force just described repeats itself for each revolution of the pinion. In the present problem the time-force diagram for tooth No. 2 must in shape necessarily be like that for tooth No. 1, the only difference being that No. 2 gets into engagement $^1/_3$ of one revolution later. Thus the time-force diagram for tooth No. 2 is immediately obtained from that for No. 1 by shifting it along the axis of time the distance Oa_2 equal to the time for $^1/_3$ revolution [Fig. 1(*b*)]. Similarly the force-time diagram for tooth No. 3 (Fig. 1(*c*)] is the same as that for No. 1 but displaced the distance Oa_3 equal to the time for $^2/_3$ revolution.

It will be seen that Figs. 1(*a*), 1(*b*), and 1(*c*) satisfy the requirements of the problem; they represent the cyclic engagement of the three teeth of the pinion; the tangential force is constant; when two teeth of the pinion are in simultaneous engagement with the gear (for example in the time interval Δt teeth Nos. 1 and 3) the sum of the tangential forces on the two teeth remains constant and equal to F; and the perfection of the gearing is reflected by the fact that the force-time diagrams are alike for all teeth with the same phase difference between each of them.

Next, attention is called to the fact that the location of the point of application of the force does not enter in any one of the author's equations for the forced torsional vibrations. Indeed, in the author's model of the pinion it is immaterial at which particular point of the disk's circumference the force acts. Thus the results will remain *precisely* the same if the forces of Figs. 1(*a*), 1(*b*), and 1(*c*) instead of acting on the corresponding teeth, were applied at one single point. This being the case, we have merely to determine the resultant of them by algebraic addition, and this resultant being constant, there will be no forced vibration.

This is the second proof that no argument or mathematics in the author's paper entitles him to the conclusion that vibrations in a pinion will be excited in a perfect pinion with constant tangential force because of the cyclic engagement of the teeth. Now the fact is, that such vibrations *do* occur, but to show this we shall need a model of a pinion different from that of the author's and a correspondingly changed mathematical analysis.

The case here is namely similar to the problem of the bridge over which a train passes, or of that of turbine wheels, in that the impressed constant force travels relatively to the object. Consider for example Fig. 2 of the present discussion, showing a beam supported at 1 and 2, and a constant force P at 1. If now the force travels with the velocity V from 1 to 2, we know that the deflection of the beam depends on the instantaneous position of the force relative to the span. Thus during the travel of the force there is a continuous disturbance of the equilibrium of the beam and as a consequence forced vibrations are excited. The point to keep in mind is, that a constant force can only then cause forced vibrations when its action is in some manner associated with a continuous disturbance of the equilibrium of the object. It is this, for example, which causes the so-called "fluttering" of disks and blades of steam turbines, and it is this element which is lacking in the author's model of a pinion.

Consider now an involute tooth (Fig. 3) wherein *I-I* is the line of engagement. As the tooth rotates the point of application of the constant tooth pressure is the intersection of line *I-I* with active profile of the tooth, but the direction of the force coincides at all times with *I-I*. Thus as shown in Fig. 3 by the pointed lines the constant tooth pressure travels along the profile of the tooth and simultaneously changes of direction relative to it. Now the tooth and the rim section to which it is joined are flexible and in this manner the displacement of the force relative to the tooth will disturb the equilibrium of the tooth for the duration of its action and so cause forced vibrations, irrespective of the perfection of the gearing and the constancy of the tooth pressure.

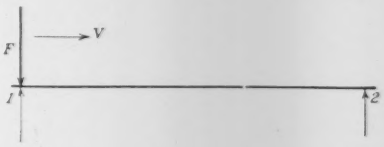


FIG. 2 BEAM SUPPORTED AT 1 AND 2 WITH CONSTANT FORCE F TRAVELING AT VELOCITY V

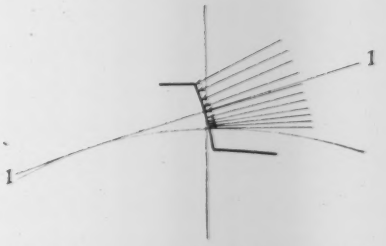


FIG. 3 CONSTANT TOOTH PRESSURE TRAVELING ALONG PROFILE OF TOOTH

A suitable model of a pinion for mathematical treatment would therefore be as follows: A rigid disk mounted on a massless shaft of the same torsional rigidity as that of the body of the pinion, flexible tooth on the periphery of the disk, and a constant force traveling successively in the manner of Fig. 3 and without discontinuity in its action along the profiles of the various teeth of the pinion. A formula derived under these conditions will truly represent the case of the perfect pinion and constant force.

In the above the author's example has been followed in considering a pinion all by itself. In practice we have at least a pair of gears with shafts and rotors having inertia as well as elasticity, all of which must be considered if the results are to be in any way representative of the case.

The last part of the author's paper (Dynamic Stresses in Pseudo-Continuous Media) begins with the statement: "The discussion so far assumed that each point of the system is free to vibrate irrespective of the state of motion of the neighboring points." This statement is far from correct, for Equations [1] to [8] are derived on the supposition of a very definite constraint, namely, that each point of the author's disk has one and the same angular displacement.

The author's model of a pseudo-continuous medium consists of the springs and two mass particles of his Fig. 3, subject to the constraint that they move on circles with l_1 and l_2 as radii. In this manner the problem becomes one of the vibrations of a system of two degrees of freedom, and there could be no objection against the solutions, which are neither new nor original, if they disclosed any thing of value to the problem of the pinion.

Having to deal with a system of two degrees of freedom, the author's formula [15] is erroneous and should be

$$\psi_1 = A_1 \cos t \sqrt{E/m} + B_1 \cos t \sqrt{3E/m}$$

$$\psi_2 = A_2 \cos t \sqrt{E/m} + B_2 \cos t \sqrt{3E/m}$$

F. HYMANS.

New York, N. Y.

TO THE EDITOR:

Mr. Hymans' objections to the writer's paper are based on a misunderstanding of the points at issue. Attention will be confined in this reply to what seem to be misunderstandings of a fundamental nature.

It is a matter of elementary knowledge that although for Equation [3] of the writer's paper a periodic disturbing function $f(t) = A \cos pt$ is set forth, the relations [5] to [8a] therefrom deduced are not limited to such cosine terms, as by a phase displacement by $\pm \pi/2$ equations identical to [5] to [8a] for *sine* terms are obtained. This is embodied in the phase factor ψ of Equations [8], [8a], and those following them.

The writer disagrees with Mr. Hymans' statement that all forces which cause vibrations irrespective of the perfection of shape and spacing of the teeth, must obviously be excluded: whatever periodic forces are acting at any one point of the periphery, the function $f(t)$

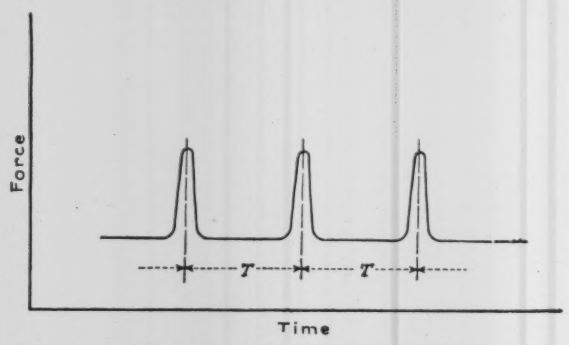


FIG. 4 DIAGRAM FOR DISTURBING FORCE ACTING AT A GIVEN POINT ON THE PERIPHERY OF THE PINION

will for that point simply resolve, within its period of continuity, into a number m of harmonics.

Moreover, it should be perfectly evident that any harmonic term of the disturbing force such as $A \cos pt$ at a given point which is stationary with respect to the revolving disk or pinion, is *not* constant at that point even when the integral of all such forces along the entire periphery may for all times be constant.

When the disturbing force is given in the form:

$$f(t) = \sum_{\lambda}^{1,2,\ldots m} \sum_{\nu}^{1,2,\ldots m} A_{\nu\lambda} \cos (p_{\nu\lambda} t - \psi_{\nu\lambda}) \ldots\ldots\ldots [1]$$

it includes all the forces acting which may result from a constant or variable torque, from imperfections of shape and spacing of the teeth, or from any other cause. In this general case, at any given point along the periphery of the disk or pinion the value of this total disturbing function will, as above, at any given time *not* be constant; moreover, the integral along the periphery will in general not be constant for all time.

If we draw a diagram for the disturbing force acting at a given point on the periphery of the pinion, we obtain a curve as given in Fig. 4, the abscissas being time and the ordinates being the intensity of the force acting at *a given* point lying on the periphery. With a force acting at a geometrical point having no dimensions, the loops of the curve would have a zero width, but with elastic bodies where the force acts on an area usually small but always finite, these loops take a given width as shown in the figure. The periodic time T in seconds will be equal to $60/n$, n being the number of revolutions per minute of the disk or pinion, and the successive loops will be the same if not outside disturbing force has a period different from T. If a disturbing force has a period different from T, then the Fourier analysis should be carried out in terms of the least common multiple of the period of revolution and the period of the force. Each point along the periphery will have a similar force diagram, displaced along the time axis as one proceeds from point to point along the periphery. The total disturbing force acting at a given time on the pinion will be given by the summation of the ordinates, corresponding to the chosen value of t, of the curves drawn for all points.

Analogy does exist between the problem of the pinions and the bridge in which a moving force is acting, if we consider a force traveling backward and forward on the bridge. It is easy to realize that if the frequency of backward and forward motion of said load on the bridge strikes a natural frequency of vibration of the bridge, resonance stresses are to be expected.

Concerning the dynamics of pseudo-continuous media, to the writer's knowledge the application of the Heaviside operational method to problems of mechanical systems presenting damped and undamped vibrations with two or any greater number of degrees of freedom has not been made before. The benefit which is derived therefrom is set forth in the last three paragraphs of the paper.

PAUL HEYMANS.

Cambridge, Mass.

Proposed Standards for Herringbone Gears

TO THE EDITOR:

The writers appreciate the comments which appeared in the December issue of MECHANICAL ENGINEERING on their criticism of the "Proposed Standard for Herringbone Gears for Commercial Use" made by Mr. H. P. Tiemann, a member of the committee that drafted the "Proposed Standard." We feel obliged, however, to correct Mr. Tiemann on one point. Mr. Tiemann states, "The yield points purport to be derived from S.A.E. specifications." This was not implied nor indicated except in the case of S.A.E. steel 3245. The values for the 50C steel and the 30C steel were not taken from S.A.E. charts and were not so indicated in our first communication. Our purpose in giving these values was to show the possible wide variation in physical properties of the same material with different treatments.

Mr. Tiemann, although he does not stress the point, substantiates very ably our criticism which caused us to include the data in question, namely, that definite information is lacking in the specifications for the materials for which working stresses were given in the "Proposed Standard."

The Proposed Standard stated "Chrome-nickel heat-treated steel (S.A.E. 3245)." The S.A.E. publish no physical properties for this steel, but quoting from page D-18, March, 1922, S.A.E. Handbook:

> For the sake of simplicity it has seemed advisable to use only average minimum figures for tensile strength, yield point, reduction of area, and elongation, based on the following considerations, heat treatment being constant:
>
> (1) The lowest yield points and tensile strengths are produced with steels at the bottom of a given range in carbon.

For these reasons the writers chose the values for S.A.E. 3250 steel. The values given by Mr. Tiemann are also logical. In view of the foregoing, the question arises, What values of physical properties and what heat treatment were intended when the allowable working stress was given as 30,000 lb. per sq. in.?

In his communication Mr. Tiemann has quoted for 50C forged steel those values given by the S.A.E. specifications for 45C steel where a variation of 5 points in carbon content is allowed. The writers quoted values taken from another authority for 50C steel and, although the variation in carbon was not specified, it can be assumed to be 5 points as this is a very common allowable variation. The fact that these two sets of values agree absolutely is another proof that more detailed information should be given.

The third point in favor of more detailed information is brought out by the figures presented by Mr. Tiemann for 30C steel. He quotes average values for S.A.E. 1025 and 1035 steels. The writers quoted values from another authority and there are differences of about 10 per cent and 18 per cent between Mr. Tiemann's and ours. Any of these values may be obtained by varying the treatment.

Our original criticism and Mr. Tiemann's comments bear out the wisdom of the A.S.M.E. in building a machine and in sponsoring research to determine the relation of the usually determined physical properties of the materials used in gears to their effectiveness in carrying the loads to which they are subjected.

FRANK A. MICKLE
CHARLES W. GOOD.

Ann Arbor, Mich.

Die Casting

TO THE EDITOR:

We have read with interest Mr. Barnard's paper on Die Casting, published in the November, 1924, issue of MECHANICAL ENGINEERING. It is an interesting one and indicates a careful study by the author of the mechanical features of the die-casting process.

We wish to call attention, however, to one important phase of the subject on which very little adequate information has ever been published, namely, the alloys used in die casting. We should like to speak with regard to zinc die-casting alloys to which we have devoted four years of continuous work, not only in this laboratory with our own die-casting machines but also in coöperation with die-casting companies.

As a result of this work we feel justified in stating that the zinc alloy given by Mr. Barnard on page 664 as representative of the zinc-base alloys is far from being representative.

Two types of zinc-base alloys are in use. One of these contains tin, copper, and a small amount of aluminum. It is the presence of aluminum in combination with tin which causes these alloys to oxidize and swell. The alloy composition given by Mr. Barnard would be perfectly stable, but to facilitate casting a small amount of aluminum is always added. These alloys have no excuse for existence as they are inferior in many essential respects to the cheaper alloys of the second type.

The second type of alloy contains only aluminum, copper, and the purest commercial grade of zinc. If made from zinc free from lead and cadmium, an alloy of this type containing 4 per cent aluminum and 3 per cent copper possesses very desirable mechanical and casting properties, and is very resistant to attack by warm, humid atmospheres. However, it cannot be recommended for use in continuous contact with steam if a slight expansion is objectionable.

This alloy is, as far as we can ascertain, used to a greater extent than any other zinc-base alloy, and it is continuing to displace other zinc-base alloys.

It may be well to point out some of the outstanding advantages of the second type of alloy, namely, one containing 4 per cent aluminum and 3 per cent copper.

1 It can be made with the purest grade of zinc more cheaply than the tin-bearing alloy can be made with low-grade zinc, because of the high price of tin.

2 When made with pure zinc it is remarkably free from hot-shortness, while the tin-bearing zinc alloys are very hot-short.

3 Its tensile strength is over 40,000 lb. per sq. in. on a $^1/_8$-in. die-cast section. The tin alloy has a tensile strength of less than 20,000 lb. per sq. in.

4 When made with pure zinc it has a high impact strength and considerable malleability, whereas the tin-bearing alloy has a very low impact strength and is brittle.

5 When made with pure zinc it resists corrosion better than the tin-bearing alloy.

We should like to bring these facts to the attention of your readers because they bear on a much neglected but very vital phase of the die-casting industry.

W. M. PEIRCE.

Palmerton, Pa.

The New A.S.M.E. Power Test Code for Stationary Steam Boilers

IN 1886 a committee appointed by The American Society of Mechanical Engineers formulated a code for the testing of steam boilers which soon became the standard practice of the profession and the basis upon which performance guarantees were drawn and settled.

At that time there were no other recognized rules for practice extant in this country. The Institution of Civil Engineers of Great Britain appointed a Committee on Tabulating the results of Steam Engine and Boiler Trials in 1897 and their report, made in 1902, is now under revision by a Joint Committee of the Institutions of Civil and Mechanical Engineers.

In the thirty-eight years that have elapsed since the adoption of the original A.S.M.E. Code it has undergone several revisions made necessary by the progress of the art. Such a revision has just been completed and the code is now available in the thoroughly up-to-date form in which it has been adopted by the Council of the A.S.M.E. as the approved standard practice of the profession.

The committee in charge of this 1923 revision consists of Edwards R. Fish, vice-president, Heine Boiler Co., Chairman; Arthur D. Pratt, Babcock & Wilcox Co., Secretary; Alex D. Bailey, superntendent of generating stations, Commonwealth Edison Co., Chicago; Albert A. Cary, consulting engineer, New York; and Edwin B. Ricketts, assistant to chief operating engineer, New York Edison Co.

The earlier 1915 draft of the code for stationary steam boilers related primarily to tests made with coal, while the latest (1923) revision covers in a complete way tests with (*a*) solid fuels, (*b*) liquid fuels, and (*c*) gaseous fuels. The use of each of these types of fuel is treated when stokers, superheaters, economizers and air preheaters are attached to the boiler.

The text of the code has been completely rewritten and the Data and Results section has been developed in an entirely new form. It now contains separate tables for each combination of apparatus, each item of which is covered by an item in a corresponding section devoted to computations. As a result of this arrangement considerable time will be saved in computing tests made according to this standard code. To further facilitate the computations and record of stationary steam boiler tests the A.S.M.E. is planning to issue in separate pad form the various data, heat balance, and computation sections.

The Development of a Domestic Polishing Leather

THE Bureau of Standards was able recently to assist a manufacturer of cutlery in connection with the leather used on the rough polishing wheels during the finishing processes. According to information given by the manufacturer it was not possible to secure an American leather satisfactory for the purpose, and it was therefore necessary to import material from a foreign country at a high cost. This imported leather also had to be subjected to a further treatment in this country, which also added to the expense.

Samples of the imported leathers both before and after the special treatment were received. As reflected by the chemical tests the leather contained a slight trace of chrome and about 3 per cent of grease. The only difference between the treated and untreated leather was that in the former the grease content was less than one-half of one per cent. The sole effect of the special treatment was that of degreasing the leather, and an immediate saving was effected since the manufacturer could readily do this himself after being advised as to the situation.

Several samples of American leather were furnished the manufacturer for test purposes and finally one was found which he advised gave complete satisfaction. This leather was tanned by a combination of the chrome and vegetable process.

Through this work the Bureau was able to effect a material saving and also to make possible the use of a domestic rather than foreign product. In commenting on this assistance, the manufacturer stated that the service was of substantial value and importance to the industry.

Wind Power for Farm Electric Plants

IN A letter from E. N. Fales one of the discussers of the above paper by F. J. Pancratz, the suggestion is made that the caption to Fig. 10 which appears in his discussion on page 681 of the November issue of MECHANICAL ENGINEERING be changed to read as follows in order to make the data consistent.:

FIG. 10 HORSEPOWER COEFFICIENTS PLOTTED AGAINST RATIO OF TIP SPEED TO WIND VELOCITY AS OBTAINED IN WIND-TUNNEL TESTS OF WINDMILL, BUT WITHOUT CORRECTIONS FOR WIND-TUNNEL WALL EFFECT

Engineering and Industrial Standardization

Substantial Progress Made in Standardization of Bolts, Nuts, and Rivets

A SPIRIT of complete harmony pervaded the meeting of the Sectional Committee on the Standardization of Bolt, Nut and Rivet Proportions held in New York on January 8. An unusually large percentage of the membership of the Committee was present and stayed through the morning and afternoon sessions. Prof. A. E. Norton, chairman of the Committee, was unable to be present on account of illness, so the Committee elected George S. Case as temporary Chairman. William J. Outcalt, the Committee's secretary, was on hand and ably assisted the chairman in the conduct of the meeting.

As part of the routine business of the Committee it was announced that J. A. Underwood, of the Favorite Stove Company, Piqua, O., replaces Frederick Will, of the Sterling Range and Furnace Co., Rochester, N. Y., as a representative of the National Association of Stove Manufacturers.

A full report was made on the informal conference on bolt and nut dimensions between representatives of the German and Czechoslovakian Standards Committees and the Sectional Committee by John Gaillard of the American Engineering Standards Committee. The Sectional Committee approved the work of the American conferrees and heartily endorsed the recommendation that steps be taken leading to a more broadly representative international conference on this subject in the near future.

Reports of the five sub-committees on the agenda were then called for in order. The action of the Sectional Committee on each report is given in brief form below.

Large and Small Rivets. The report of Sub-Committee No. 1, Lieut. G. W. Nelson, Chairman, on small rivets having a diameter of $^{7}/_{16}$ in. and under and the report on tinners', coopers', and belt rivets was, in the absence of Chairman Nelson, presented by H. C. Weidner, a member of the Committee. Mr. Weidner explained that the Sub-Committee desired to make slight changes in certain of the proposed dimensions and to modify somewhat the arrangement of the proof tables distributed to the Sectional Committee on December 30. Since these changes were not of a vital nature the Committee ordered this report to letter ballot.

Wrench-Head Bolts and Nuts and Wrench Openings. Commdr. J. B. Rhodes, Chairman, presented the report of Sub-Committe No. 2. It includes tables covering the various types and finishes of hexagonal and square bolt heads and nuts, e.g., finished, semi-finished, and rough bolt heads and nuts, finished and rough jam nuts, special light nuts, machine-screw and stove-bolt nuts, cap and set screw heads, open-end wrench openings. These proposed standards were thoroughly discussed and a number of important changes and simplifications in the tables were recommended. The report was then ordered to letter ballot of the Sectional Committee after Chairman Rhodes had revised it in line with the suggestions at this meeting.

Slotted-Head Screws. Chairman E. Winsor Reed was present and opened the discussion on the report of Sub-Committee No. 3 by moving for its approval and submission to letter ballot after certain slight changes had been made in some of the head dimensions. He also reported that his sub-committee was not in agreement as to the advisability of publishing at this time standard screw and thread lengths. His amended report, therefore, excluded the tables of these dimensions previously mailed to the members of the Sectional Committee. By a vote of those present the Secretary was directed to send this report in revised form also to the members of the full committee for final ballot by mail.

Track Bolts and Nuts. A progress report only was made by Sub-Committee No. 4. It was formally presented by Chairman Clarence W. Squier and covered the head, neck, and body dimensions of proposed standards for two track bolts, one with an elliptic neck and one with an oval neck. The types of bolts and their dimensions as proposed in this report are identical with those forming a report on this subject by a committee of the American Railway Engineering Association.

At a subsequent meeting this sub-committee plans to present a revised report on track bolts and to then include its recommendations for standard track nuts.

Round Unslotted Heads. Standard dimensions for the heads of common carriage bolts, fin-neck carriage bolts, ribbed carriage bolts, step bolts, countersunk carriage bolts and button-head machine bolts, having been approved already by letter ballot of the Sectional Committee, Chairman William M. Horton of Sub-Committee No. 5 presented to the meeting in draft form a set of supplementary tables containing recommended standard lengths of these types of screws and their corresponding thread lengths. These proposed standard lengths were based on data gathered as the result of a questionnaire sent out by Sub-Committee No. 7 on Body and Material, Carl F. Meyer, Chairman.

Sub-Committee No. 5 recommended that copies of the length tables which form a supplement to its first report be mailed to the members of the Sectional Committee for their review and approval when reports of other Sub-Committees are sent out.

Plow Bolts. In the absence of Chairman E. P. Stahl, due to illness, O. B. Zimmerman, a member of Sub-Committee No. 6 and the official representative of the National Association of Farm Equipment Manufacturers, presented the proposed standard dimensions for plow bolts. This report covers four different bolts of this type, both regular and repair. It constitutes a slight modification of the dimensions proposed by the National Association of Farm Equipment Manufacturers at a simplification conference called by the Department of Commerce in Washington on February 19 and 20, 1924. The tables forming this proposed standard include the dimensions of the heads and also the body and thread length. This sub-committee's report also was ordered to letter ballot of the Sectional Committee.

The screw threads of these bolts, screws, and nuts are to be specified as the American (National) Standard (A.E.S.C. No. B 1a-1924). The various types of bolts and screws will, of course, have threads cut or formed to one or the other of the two standard series of pitches and to one or more of the different classes of fit provided for by the screw-thread report. For instance the thread specified for plow bolts will be coarse-thread series—Free Fit (Class 2).

A.E.S.C. Elects Officers

AT THE annual meeting of the American Engineering Standards Committee on December 11, Charles E. Skinner, a representative of the American Institute of Electrical Engineers, was elected chairman for the year 1925, and Charles Rufus Harte, representative of the American Electric Railway Association, vice-chairman.

The other members of the Executive Committee for the year 1925 are as follows:

RALPH G. BARROWS—U. S. War Department
GEO. K. BURGESS—U. S. Department of Commerce
JOHN A. CAPP—American Society for Testing Materials
COKER F. CLARKSON—Society of Automotive Engineers
W. A. E. DOYING—The Panama Canal
STANLEY G. FLAGG, JR.—The American Society of Mechanical Engineers
E. A. FRINK—American Railway Association—Eng. Div.
C. S. GILLETTE—U. S. Navy Department
O. P. HOOD—U. S. Department of the Interior
SULLIVAN W. JONES—American Institute of Architects
THOMAS A. MACDONALD—U. S. Department of Agriculture
CHARLES A. MEAD—American Society of Civil Engineers
A. H. MOORE—Electrical Manufacturers' Council
A. CRESSY MORRISON—Gas Group
DANA PIERCE—Fire Protection Group
F. L. RHODES—Telephone Group
S. G. RHODES—Electric Light and Power Group
C. F. W. RYS—Association of American Steel Manufacturers
ETHELBERT STEWART—U. S. Department of Labor
GEO. C. STONE—American Institute of Mining Engineers
ALBERT W. WHITNEY—Safety Group.

Albert W. Whitney, the retiring chairman, is at present in Lima, Peru, attending the first Pan-American Conference on Standardization.

Developments in Industrial Standardization during 1924

NOTABLE developments in the industrial standardization movement, including important progress in the mechanical and mining industries and in the safety field, its further extension into managerial and trade-association activities both here and in Europe, and steps looking toward it in Latin America, have taken place during 1924, according to an announcement of the American Engineering Standards Committee.

Most of the great firms are now coming to have some definite organization for their standardization work, instead of leaving it as a more or less incidental part of their engineering and production activities. Increasing competition is bound to result in some form of definite organization for the work in the majority of all but the smallest companies. This has already taken place in Germany, where more than 1000 firms have such organizations, some of the larger companies having as many as 100 or even 200 members of their staff devoting full time to such activities. The increase in the number of associations and companies affiliated in the membership of the American Engineering Standards Committee is a notable step in this direction.

This interest on the part of management is shown by the fact that standardization is becoming one of the most important and appreciated activities of trade associations, which are the principal mechanism through which management arrives at collective industrial policies. For example, 150 trade associations are officially participating in the work of the A.E.S.C. through accredited representatives.

In all, about 70 standards have been approved by the American Engineering Standards Committee, and 100 others are under way. Of these, 32 have to do with civil engineering and the building trades; 26 with mechanical engineering; 15 with electrical engineering; 4 with automotive subjects; 11 with transport; 1 with ships and their machinery; 14 with ferrous metals; 15 with non-ferrous metals; 12 with chemical subjects; 2 with textiles; 16 with mining; 5 with the wood industry; 1 with the paper and pulp industry; and 11 projects with topics of a miscellaneous or general character.

A particularly important feature has been the development of the work on mining. Until the very recent past, little had been done in the mining industry. The pioneer work in this field has been done by the U. S. Bureau of Mines, which was first in the field, and by the American Mining Congress. Work on no less than ten mining projects has been started under A.E.S.C. procedure during the last year. These include codes for rock dusting, mine illumination, ventilation, use of explosives in coal mines, and underground transportation.

The most important piece of work completed by the A.E.S.C. in the mechanical field during 1924 was the promulgation of the standard for screw threads, a subject which touches practically every industry. This was worked out in coöperation with the National Screw Thread Commission. Good progress has been made in two other far-reaching subjects: gages and systems of gaging, and pipe flanges and fittings. Parts of the work on both of these subjects are now nearly ready and will be issued soon.

Work on dimensions and tolerances for bolts, nuts, and rivets is also well advanced. This includes hexagonal and square bolt heads and nuts, cap and set screws, slotted-head machine and wood screws, track bolts and nuts, carriage bolts, plow bolts, and large and small rivets. At an informal conference of representatives of the American, Czechoslovakian, and German committees on the first of this group it was recommended that there be held a general international conference looking toward international agreement so that there may be international interchangeability in regard to wrenches, nuts, and bolt heads.

Technical standardization is playing an increasing role in matters of safety. At the recent conference on street and highway safety, called by the Secretary of Commerce, it was strikingly evident that patient detailed standardization of the technical details of traffic facilities and control is essential to the solution of this outstanding problem in public safety. Important examples of such work is that of the A.E.S.C. on the unification of colors for traffic signals, and on a code for automobile brakes and brake testing. The importance of the general problem was summarized by Mr. Hoover in the statement that the number of fatal accidents, 22,600 per year, is one-third as great as the total American fatalities during the war.

In the field of industrial safety, substantial progress has been made on a program of some 40 codes, most of which are applicable for factories. Thirteen of these have been completed, and work on half of the remainder is well advanced. Codes for logging and sawmill machinery, laundries, and school lighting, and a revision of the code for punch presses, were completed and approved during the year.

Standardization activities in foreign industrial countries continue to increase. Among the newer national organizations those in Czechoslovakia and Japan are showing great activity. The former has approved 5 standards, and has no less than 176 other projects under way, and the latter is working on 47 projects. In all there are now nineteen national standardizing bodies, as follows: Australia, Austria, Belgium, Canada, Czechoslovakia, Finland, France, Germany, Great Britain, Holland, Hungary, Italy, Japan, Norway, Poland, Russia, Sweden, Switzerland, United States.

Heretofore there has been no very active development of standardization activities in Latin America, and hence the Pan-American conference on standardization, which opened in Lima, Peru, on December 23, is a notable event. The general idea of such an undertaking originated with the Latin-American countries. While it is not expected that it will be feasible to undertake much if any technical work at the first conference, it is anticipated that the way will be paved for extremely valuable developments.

The Federal Specifications Board has now adopted nearly 300 specifications. These are used as a basis of purchase throughout the Federal Government. The A.E.S.C. has continued its coöperation in this work, and during the year has circulated more than 100 of these specifications for criticism, in order to determine their acceptability in industry before official adoption by the Government.

The third year of the work of Mr. Hoover's Division of Simplified Practice has shown extensive development. In all, 26 simplifications have already been carried through, 10 others are in the final stages, and 45 additional surveys are now under way. Two hundred industrial groups are coöperating in the various projects.

The U. S. Chamber of Commerce and the A.E.S.C. are cooperating closely in this work. In general, the Division concentrates upon such eliminations as it is possible to carry out from a survey of statistical production data alone. An exception to this is the activity in connection with the standardization of lumber sizes and grading rules for soft woods, which constitute the Division's most notable achievement.

The Dictionary of Specifications now being prepared by the Bureaus of Standards and of Foreign and Domestic Commerce is nearly ready for publication. This will consist of a classified list of all of the more important purchase specifications in existence in this country. It has been developed primarily for the use of public purchasing bodies, to which, as well as to industries in general, it should be of great service.

The coöperation of the Federal Government with industry through the machinery of the A.E.S.C. steadily increases; in fact, one or more arms of the Government are coöperating in nearly every one of the A.E.S.C. projects. The Bureau of Standards and the Federal Specifications Board jointly maintain a liaison officer in the offices of the A.E.S.C.

Code of Standard Practice in Steel Construction

SINCE the use of structural steel came into existence about thirty-five years ago, there has developed an industry engaged in the fabrication and erection of this material which at the present time is annually furnishing over $300,000,000 worth of material to the public.

During this period of evolution it is obvious that many inconsistent practices should have come into existence, and so the American Institute of Steel Construction, representing the in-

dustry between the rolling mills and the buying public, has undertaken the codifying of the various conditions, with a view of establishing uniform practice.

The Institute's Specification on the design, fabrication, and erection of structural steel has been received with widespread approval, and this Code of Standard Practice is now being issued to cover conditions not touched in the Specification.

The following are the subjects of the ten sections into which this new code is divided:

1 Design
2 Classification
3 Invoicing
4 Drawings and Specifications
5 Good Workmanship and Standard Practice
6 Inspection and Delivery
7 Erection
8 Delays in Prosecution of Work
9 Extra Work
10 Proposals and Contracts.

The report clears up definitely the basis of invoice weights. It defines what constitutes a plumb building, something which has never been done before. On the question of delays, rigid requirements have been set up which tie the hands of the seller equally with those of the buyer in every detail, making the question of compensation and adjustments for such delays simple, definite, and free from obscurity or the countless loopholes that have been the source of so much annoyance to the industry and the users of structural steel.

In connection with the code, the Institute has worked out a standard form of proposal, under which the seller agrees to furnish to the buyer certain materials and labor, "in accordance with the conditions of the Code of Standard Practice of the American Institute of Steel Construction." Execution of this proposal by buyer and seller is all that is necessary to make the code operative on any contract.

For further information concerning the aims and organization of the A.I.S.C. our readers may communicate with its engineering offices at 1052 Leader Building, Cleveland, or the executive offices at 352 Madison Avenue, New York.

Standard Methods for Rating Rivers

THE U. S. Geological Survey has proposed to the American Engineering Standards Committee that a national agreement be worked out on methods of rating the water power of rivers. In the request the Survey states:

> The engineers of the Geological Survey have struggled with the problem of rating rivers . . . and have within a few years adopted the rule of rating on the basis of 50 per cent and 90 per cent flow. This rule has been adopted by other organizations but is by no means universally used. There is therefore much confusion in statements relating to the capacities of rivers for developing power and a real need for the adoption of a standard. The necessity for a standard was obvious at the World Power Conference in London, as statements of power resources for different countries were made on different bases and therefore were not comparable. Any action taken in this country should recognize the practice in other countries and should conform, if practicable, to a world standard.

In response to this request the A.E.S.C. will communicate with other organizations which may be interested, and if the general sentiment is in favor of the undertaking a sectional committee will be organized for the work. Expressions of opinion on the subject are invited by the American Engineering Standards Committee, 29 West 39th Street, New York City.

Simplified-Practice Recommendation on Sheet Metal

IN ACCORDANCE with the unanimous action on October 14, 1924, of the general conference of representatives of manufacturers, distributors, and consumers of sheet steel, the U. S. Department of Commerce, through the Bureau of Standards, now recommends a group of simplified sizes and weights of sheet steel.

This general conference was held in Atlantic City, N. J., on October 14, in conjunction with the meeting of the Metal Branch of the National Hardware Association of the United States. Previous to this conference, in May, 1923, the chairman of this association, W. H. Donlevy, had appointed a committee to study the sheet-steel industry and to prepare a set of recommendations on the elimination of unnecessary varieties. To pursue this work intelligently it was necessary to make a complete survey of the sheet-steel industry. The period taken for the survey covered the last six months of the year 1922, and every gage and size ordered by distributors during the period was included in the survey. The total number of items reported by the mills amounted to something over 20,000. The organization of the National Association of Sheet and Tin Plate Manufacturers assisted materially in compiling the total figures which were embodied in the survey.

The committee's report was presented to the October conference, and after a general statement by A. E. Foote of the Division of Simplified Practice and a full discussion by those present it was accepted with slight modifications. This report may be summarized as follows:

Galvanized Flat Sheets
: Ninety-five (95) sheet sizes in gages from No. 14 to No. 30, inclusive

One-Pass Cold-Rolled Box-Annealed Sheets
: Forty-three (43) sheet sizes in gages from No. 18 to No. 29, inclusive

Blue Annealed Sheets
: Fifty-nine (59) sheet sizes in gages from No. 10 to No. 16, inclusive

Corrugated Roofing and Siding
: Galvanized: Present standard widths and corrugations—In even-foot lengths 5 ft. 0 in. to 12 ft. 0 in. in 28 gage and heavier, *even gages.*
: Painted: Present standard widths and corrugations—In even-foot lengths 5 ft. 0 in. to 12 ft. 0 in. in 28 gage and heavier, *even gages.*

Roofing—(All other styles and patterns)
: Galvanized: Present standard styles and patterns in 28 gage and heavier, *even gages.*
: Painted: Present standard styles and patterns in 28 gage and heavier, *even gages.*

Only Eleven Sizes of Steel Reinforcing Bars after January 1, 1925

AS A RESULT of a conference held at the Department of Commerce in Washington last fall, the following recommendation was made relative to the manufacture, distribution, and use of steel reinforcing bars—round and square:

> In accordance with the unanimous action of the joint conference of representatives of manufacturers, distributors, and users of square and round steel reinforcing bars, the United States Department of Commerce, through the Bureau of Standards, recommends that the recognized sizes of square and round steel reinforcing bars, in terms of cross-sectional area, be reduced to the following:

Size in Inches	Area in Square Inches
1/4 Round	0.049
3/8 Round	0.110
1/2 Round	0.196
1/2 Square	0.250
5/8 Round	0.307
3/4 Round	0.442
7/8 Round	0.601
1 Round	0.785
1 Square	1.000
1 1/8 Square	1.266
1 1/4 Square	1.563

> It is further recommended that this reduced list of sizes becomes effective as applying to new production January 1, 1925, and that every effort be made to clear current orders and existing stocks of the eliminated areas before March 1, 1925.

This recommendation has received practically the unanimous acceptance by manufacturers, distributors, and users throughout the entire United States.

At a recent meeting of the Concrete Reinforcing Steel Institute, made up of members of the reinforcing-bar interests of the United States, these recommendations were accepted.

Another step forward to more simplified and economical building has been thus attained.

Outstanding Developments in Fuels Engineering and Research during 1924

By H. W. BROOKS,[1] PITTSBURGH, PA.

THE harsh lessons in fuel conservation learned in 1920 when spot bituminous prices advanced to a peak of 725 per cent of prewar normal, and again in 1922–1923 when a peak of 450 per cent was reached, continued to bear fruit in increased interest in efficient fuel utilization during 1924, when coal prices ranged from 160 to 180 per cent of the prewar levels. It was appropriate, therefore, that one of the major subjects of discussion by the engineers of 35 nations, gathered at the World Power Conference in London, June 30 to July 12, should have been that of fuels—their origin, production, handling, processing, and efficient utilization.

It was brought out in the introductory speech of the Prince of Wales that it was the purpose of this Conference to initiate a world coördinating agency dealing with power progress and equipment, with natural resources, with conservation, and with standardization in design and manufacture. "An effort to create for industry," said he, "what it was intended the League of Nations would do for politics," was the true purpose of the World Power Conference, and it was the general opinion of those familiar with the Conference that same was a success.

During the year there was published[2] a preliminary draft of the new Test Code for Solid Fuels as formulated by the Fuels Sub-Committee of the Power Test Codes Committee of the A.S.M.E.

Origin of Coal

Late during 1923 Dr. Franz Fisher, of Muelheim, Germany, proved[3] rather conclusively that the theory which had been previously accepted by some, as to the origin of coal from cellulose, is untenable and that its actual origin was lignin. Work by Dr. Reinhardt Thiessen[4] of the U. S. Bureau of Mines, as well as by investigators in England, apparently confirmed the new theory.

Coal Beneficiation

Increased mining costs, coupled with the relatively slack business of the year has militated against unusual progress in installation of coal cleaning and processing plants, except in Alabama where several large new washeries have been laid down. The usual result of low-priced coal has been apparent in the cleaner coal shipped during the year due to more careful mining methods.

Of the country's bituminous production beneficiated, the approximate average of 5 per cent remains about the same as last year. Alabama continues in the lead with about 50 per cent of total production, closely followed by Washington. Illinois follows with about 15 per cent and Pennsylvania with about 10 per cent. An interesting new dry-cleaning process has been developed at St. Benedict, Pa., claiming a very high capacity on a single table, as well as the ability to dry with natural unsized fuel from 0 in. to 2 in. in a single operation at the rate of 100 tons per hour. A new all-table plant of Overstrom universal tables, utilizing the differential motion from unbalanced pulleys has been installed at Morris Run, Pa., while another all-table plant has been installed at Rosita, Coahuila, Mexico. In the anthracite fields, at Scranton, Pa., there was installed the first Rheolaveur process plant in the United States, the type having proved very successful in Europe. Great extension of the use of the Chance sand process of treating anthracite has been made.

Complete Gasification of Coal

The year 1924 saw the first preliminary tests[5] of the large commercial-scale complete gasification plant at the Hazel Atlas Glass Company at Washington, Pa.

Additional interesting experiments have been carried on by the Worcester Gas Light Company, of Worcester, Mass., utilizing oxygenation in gas producers in an attempt to raise the heating value of the gas to approximately 300 B.t.u. by elimination of inert nitrogen.

Subsequent to the publication of a paper by W. W. Odell[1] late in 1923, further interest has been manifested and progress made in the practical use of bituminous coal in carburetted-water-gas apparatus. Developments during 1924 are described by Odell in a recent Bureau of Mines publication.[2] Satisfactory progress is reported in application of recuperators to various processes using gas-fired furnaces in the industries and the supplanting of less efficient with more efficient types.

Carbonization of Coal

In high-temperature by-product coke-oven practice the principal developments have been in the extension of the chamber method of carbonization for gas making in an attempt to make better domestic coke.

The development of the Koppers-Becker oven with cross-over flues offers new possibilities in uniformity of heating and shortening of coking time.

In Germany the Collin oven[3] heats alternately from the top and bottom (instead of entirely from the bottom) in an endeavor to secure more uniform heating. It utilizes no vitrified refractory roof, employing only stamped fireclay pressed in. Thus it is said that repairs may be made without disturbing the superstructure.

Two new schemes for the dry cooling of coke are mentioned in this same article,[3] one designed by Sulzer for gas-retort installations, and one by Collin for their coke ovens.

The Sulzer device cools with air (recirculated) with some combustion of coke, the heat being absorbed in waste-heat boilers. There is an installation at the Rotterdam gas works.

The Collin device consists of a closed chamber located under the discharge floor with capacity for cooling the coke from three ovens. The cooling is done by circulating flue gas and the heat is absorbed in waste-heat boilers.

Perhaps the outstanding development in low-temperature carbonization has been the commercial-scale experiment of the Caracristi-Piron method installed at the Walkerville, Ont., plant of the Ford Motor Company which has not yet been installed sufficiently long to permit conclusive results to be published. Another interesting American commercial-scale low-temperature-carbonization project has been the Carbocite process of "Thermodizing," by which the raw coal is first oxidized, driving off the free moisture in an attempt to render the coal non-sticking for subsequent carbonization in rotary retorts. Numerous other experiments[4] have been carried on, both at home and abroad, none of them having at this date conclusively proved themselves economically and commercially practicable at present prices of oils, tars, and by-products.

The Canadian Department of Mines announced[5] that Canadian lignite had been carbonized by them in the Hood-Odell carbonizer at a price of $4 per ton of charcoal including all charges.

Further progress in slagging gas producers in the United States was described in the *Iron and Steel Electrical Engineer*, vol. 1,

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[1] Fuel Engineer, U. S. Bureau of Mines. Mem. A.S.M.E. Report prepared at request of Fuels Division of A.S.M.E.

[2] Mechanical Engineering, vol. 6, no. 9, Sept., 1924, 558–562.

[3] Fisher, Franz, and Schrader, Hans; Enstchung und chemische Strucktur der Kohle: 29 edition. Verlag von W. Gerardet, Essen, 1922.

[4] The Origin and Constitution of Coal, to be published soon in the Proc. of the Wyoming Historical and Geological Soc., Wilkes Barre, Pa.

[5] Address before Engineers' Society of Western Pennsylvania, Feb. 5, 1924, by H. O. Loebell.

[1] Efficiency in the Use of Bituminous Coking Coal as Water-Gas-Generator Fuel. Bureau of Mines Technical Paper 274.

[2] Coal & Coke Mixtures as a Water-Gas-Generator Fuel, W. W. Odell, Bureau of Mines Technical Paper 284.

[3] Neuerungen im Kokereiwesen. H. Illies. *Brennstoff-Chemie* 5, 161–6, 189–95, 234–40 (1924) June 1 and 15 and August 1 issues.

[4] Practical Coal Carbonization, by A. R. Powell, Mechanical Engineering, vol. 46, no. 7, pp. 389–394, July 1924.

[5] Haanel, B. F., The Fuel Resources of Canada and Their Utilization for the Production of Power: Paper read before the World Power Conference.

no. 9, September, 1924, page 457. Commercial-scale slagging producers have been installed in France at Bully-Granay, also at St. Etienne, so far without completely demonstrating their ability to operate continuously nor their economic feasibility.

The use of small charcoal gas producers for heavy auto trucks has been adopted in Paris and Vienna to the extent of nearly 100 trucks equipped to date in these two cities. A similar truck is manufactured in England, principally for export and colonial trade. The application is limited on account of lack of large commercial supplies of charcoal. Research is progressing in hopes of developing the automotive-type gas producer for use with bituminous coal.

The present status of coal carbonization in general has been brought out in a book by Horace G. Porter entitled Coal Carbonization, while the present status of low-temperature carbonization in Europe is given in a book entitled Low-Temperature Carbonization, by Messrs. Lander and McKay.

MINE-MOUTH PLANTS

Continued extensions and additions to mine-mouth plants have been built or contracted for during the year, among which may be mentioned the increase at the Colfax plant of 5 boilers, each of 2650 hp., also at Springdale. Progress has continued on the Wabash River plant of the Indiana Electric Corporation, a 40,000-kw. plant with a 100,000- to 200,000-kw. ultimate.[1] A new pulverized-fuel mine-mouth plant has been contracted for by the Union Gas and Electric company through their subsidiary, the Columbia Power Company.

FUEL-BURNING EQUIPMENT

Comparing the reports of installations of automatic stokers published by the U. S. Department of Commerce showing 1923 versus 1924 installations, it appears that the stoker industry, particularly in the larger installations, has suffered at the hands of its new competitor pulverized fuel. There has been a steady falling off in the number of installations made. To date only, during the months of October and November, has the stoker business for 1924 passed that of 1923.

In England there has been brought out a new type C stoker, consisting of laminated-steel grates built of narrow steel links only about $1/4$ in. wide and with air spaces less than $1/32$ in. so that finely divided inferior fuel can be burned with a minimum of riddlings. The grate travels underneath, bodily immersed in a water bath, while the grate surface is not flat but by means of supporting rollers rises from the hopper and falls again at the ash end. Air supply is on the compartmented principle. Leakage air, passing at the back, is guarded against by the thick-ash seal and the shape of the grate. Two units are under construction for the Montreal Tramways. In the United States details in the development of the longer superstokers of unusually large coal-burning capacity initiated during 1923 has continued during the present year. "In some instances they may be said to have been suffering from the pains incident to too rapid growth though their performance on the shole has been very satisfactory."[2] Three 1550-hp. Springfield boilers, provided with water-cooled walls, with furnaces 24 ft. $3\frac{3}{4}$ in. between side walls and 16 ft. 4 in. from front to rear walls, providing a total furnace volume of approximately 7160 cu. ft. and with radiant-type superheaters, have been installed at the Hell Gate Station of the United Electric Light and Power Company.

Another notable superstoker installation of the year is the new Kearny station of the Public Service Corporation of New Jersey. The initial installation includes 12 stokers, serving 23,600-sq. ft. boilers, each being 16 retorts wide and 37 tuyeres deep with a coal-burning capacity of 30,000 lb. per hour. The furnace is 26 ft. wide, 16.5 ft. deep, and 17 ft. high from the bottom of the crusher rolls.

"During 1924, for the first time it has been possible to give test data on air-heater installations under American conditions of fuel and operation."[3] The following are typical 1924 air-heater installations: International Paper Company, New York Edison Company, Commonwealth Edison Company, Consumers Power Company, New Castle Electric Supply Company (England), Houston Lighting and Power Company, etc.

"Very gratifying progress has been made on the mixing of furnace gases on chain-grate stokers, underfeed stokers, and other forms of fuel-burning equipment. The results of experiments quoted in the report indicate that relatively large savings are possible by proper mixing of furnace gases." (See Design of Furnaces for Burning Small Sizes of Anthracite, read before A.S.M.E., Jan. 15, 1924, by A. R. Mumford, of the New York Steam Corporation, also Adirondack Power and Light Company's experiments with front and rear arches and a mixing chamber above the opening between the two lower arches.)[1]

The past year has witnessed the first stoker installations where water-cooled boiler furnaces have been applied to power-plant boilers to any considerable extent. Notable installations are the Grand Rapids and Saginaw River Stations of the Consumers Power Company, the Waterside Station of the New York Edison Company, and the Hell Gate Station of the United Electric Light and Power Company.

In the application of stokers to locomotives, the New York Central, Erie, and other roads have installed locomotive stokers for heavy passenger locomotives for the first time, while progress in the installation of locomotive stokers on heavy freight locomotives has continued at the normal rate of increase—a majority of the heavy locomotives built during the year being so equipped. Owing to business uncertainty the output of locomotives during 1924 has been nearly 1000 locomotives short of the normal rate of increase.

The steamship *Swartenhondt*, built for service between England and Holland this year, is the third ship which has been equipped with stokers, and a fourth ship of the same line will shortly be put in commission. Stoker equipment apparently has proved a success since, after equipping two ships with it successfully, similar equipment has been put on a third ship and ordered for a fourth. On recent trials the horsepower developed was 3450 against 3100 normally, the installations consisting of 4 B. & W. marine-type boilers, each equipped with a mechanical stoker 6 ft. long by 12 ft. wide.[2]

The report of the N.E.L.A. Prime Movers Committee on Stacks and Flues gives, for the first time, dependable information backed up by test data on this subject. Research work on the proper application of refractories in boiler furnaces has been started by the U. S. Bureau of Mines in coöperation with 18 large central-station operators, while this Bureau has also initiated a study of refractory application in steel-furnace practice. An interesting contribution on fluxing action of different coal ashes on different refractories has been published in the reference given below.[3]

PULVERIZED FUEL

As in previous recent years, the total increase in square feet of boiler heating surface fired with pulverized fuel has practically doubled over 1923 in spite of the uncertainties of the business outlook. Total business done is estimated to be about 106,000 to 110,000 b.hp. At Cahokia, Ill., there has been installed the first large pulverized-fuel installation with the new fin-type water-cooled furnace. At Pittsburgh, Pa., the new Cecil plant of the Allegheny County Steam Heating Company, with a single boiler of 32,750 sq. ft. of heating surface in one unit (including coolers and water screens) gives the world's largest single boiler installation and the greatest boiler horsepower per square foot of ground area in existence. Other notable pulverized-fuel installations completed during the year included the Trenton Channel plant of the Detroit Edison Company, which is the third large central station to be fired exclusively with pulverized fuel; the Middletown plant of the Metropolitan Edison Company, consisting of three 14,710-sq. ft. boilers; the Valmont station of the Denver Gas and Electric Company, four 14,00-sq. ft. boilers; 3 units of 27,680 sq. ft. each at the Colfax station of the Duquesne Light Company; and the stand-

[1] *Power Plant Engineering*, vol. 28, no. 12, July 1, 1924, pp. 682–692.

[2] From the 1924 report of the Prime Movers Committee of the N.E.L.A.

[3] From the 1924 report of the Prime Movers Committee of the N.E.L.A.

[1] Recent Development in the Burning of Anthracite Coal, W. A. Shaudy and R. C. Denny. MECHANICAL ENGINEERING, vol. 46, no. 11a, p. 854, Mid-November, 1924.

[2] Stokers on Ship Board, *Combustion*, vol. 11, no. 3, September, 1924, p. 228.

[3] Brennan, J. J., Effect of Coal Ash on Refractories: *Combustion*, June, 1924, pp. 418–422.

by plant of the Winnipeg Hydro-Electric System, Winnipeg, Manitoba, which has been designed to burn lignite coal exclusively. Among the important plants now in the course of erection are the Miami Fort plant of the Columbia Power Company and the Peoria plant of the Illinois Electric Power Company. The New York Edison Company has decided to install pulverized-fuel equipment in its new 14th Street station after extensive tests at Sherman Creek.

Interesting research has been initiated with a view toward decreasing the volumes necessary for combustion in pulverized-fuel furnaces, though no radical developments applicable commercially have yet been described in the technical press. The long-tube Cannon furnace and the well-type furnace with tangential jets producing a centrifugal burning action present interesting possibilities for the future.

Pulverized fuel has been transmitted pneumatically a distance of 5400 ft. through a 5-in. pipe with about 360 cu. ft. of air per ton, using but one to two kilowatt-hours per ton of coal conveyed.

Complete combustion control of pulverized fuel-fired boilers has been brought to commercial success whereby the operator is relieved of the continuous detailed adjustments necessary to maintain the proper relationship between fuel and air and at the same time meet the load demands. This results not only in increased thermal efficiency but increased life of brickwork and reduction of labor in operation.

The Chilean State Railways announce very successful results on a Mikado locomotive equipped with pulverized fuel, saving nearly 10 per cent of coal consumption, as well as using a 11,000- instead of a 13,500-B.t.u. coal. Additional installations of pulverized fuel in locomotives have also been made on the Swedish and Italian State Railways.

Colloidal Fuel

J. T. Dunn, of New Castle on Tyne,[1] gives cost per million B.t.u. of fuel oil at 47.1 cents against the cost per million B.t.u. in colloidal fuel of 41.8 cents.

Conversion of Coal into Oils

Dr. Frans Fisher, of Muelheim, Germany, at the World Power Conference, London, summarized present status of research in this field as follows:

1 Only certain constituents of coal can be converted into oils by means of destructive distillation there. In this way the larger molecules of the bitumen are broken up into smaller molecules. About 10 per cent of the low-temperature tar is low boiling and has the characteristics of gasoline; the greater part boils above 200 deg.

2 Theoretically, it is possible entirely to convert coal into hydrocarbons by means of hydrogenation. Practically, however, attempts that have been made show that coal is only partly liquefied, the rest becoming soluble only. The products of hydrogenation are usually high-boiling.

3 A third possibility for conversion of coal into oils is provided by synthesis from gases. As opposed to the destructive distillation and hydrogenation, larger molecules are synthesized from smaller molecules. By gasifying coal to water gas, the latter may be transformed into synthetic oil by means of a high-pressure contact process. The synthetic oil mixture, synthol, boils below 200 deg., and as it proves to be a suitable substitute for gasoline or benzol, may be employed as motor fuel.

The Bergius process in Germany claims to be able to convert coal into liquid hydrocarbons by hydrogenation on a commercial scale, though it is understood their experiments to date consist principally in high-pressure cracking of low-grade fuel oils. Similar research has been conducted in England by Professors Haldane and Graham, and is being initiated by Audibert in France.

High-Temperature Cracking of Oil

The further diminution of the nation's oil resources caused by ever increasing demand for motor fuels has hastened the commercial-scale development of high-temperature cracking. A classification and comparison of the various processes employed to date comparing twelve processes used in the United States giving dimensions of apparatus as well as data on temperatures and pressures employed, quantities of raw oil charges, percentages of gasoline obtained, etc. is given in the reference.[2]

[1] Colloidal Fuel, Part II, Pulverized and Colloidal Fuel, pp. 175–193. J. T. Dunn.

[2] The Manufacture of Gasoline by the Cracking of Heavier Oils, by C. M. Johnson. MECHANICAL ENGINEERING, vol. 46, no. 12, pp. 879–885, December, 1924.

Motor Fuel

The commercial introduction of ethyl gasoline, discovered in the laboratories of the General Motors Research Corporation, has made possible higher compression, and hence higher efficiencies in automotive motors. It has been described in the *Journal of Industrial and Engineering Chemistry* and in the Proceedings of the Society of Automotive Engineers.

There has been an increasing appreciation by the public that in the use of fuel oil for internal-combustion engines limitations are due more to viscosity than to gravity, for with high-viscosity oils liability of trouble with entrained water and dirt which have not had opportunity to settle out, is increased.

Industrial and Domestic Oil Burning

Increasing prices of fuel oils in comparison with relatively low prices for coal have served to somewhat slow down the rate of increase of installation of oil-burning equipment for stationary heating and power services. Progress is reported in the development of new and more efficient fuel-oil-burning equipment. Special conditions, in naval, marine and locomotive service in oil-producing districts justify the rapid growth in such installations during 1924.

Summary

Except in the field of scientific coal and gasoline technology, developments during the year in fuels engineering have not involved the discovery of new fundamentals but rather the restatement of old principles in forms more adaptable for efficient and durable service. Ever-increasing interest of financiers and industrialists in fundamental research coupled with the markedly improved business conditions which usher in the new year portend a still further stimulation in fuels engineering during 1925.

High-Temperature Insulation

UNTIL a few years ago, radiation losses from heated equipment were considered an uncontrollable source of waste. The first intelligent attempt at reducing heat losses in modern industry was the use of insulation for covering steam pipes. Even this development is comparatively recent, although at the present time practically all steam pipes are covered with insulating material of some kind.

For some time there was a general belief that since air is a poor conductor of heat, air spaces built into the walls of boilers, furnaces, etc. would prevent or reduce heat loss through the walls. Messrs. Ray and Kreisinger of the United States Bureau of Mines ran a series of exhaustive tests on air spaces used as an insulation and showed that this artifice defeats its own purpose at high temperatures because of the fact that the hot surfaces of the air space radiate heat so rapidly that a greater amount is lost across the space by radiation than would be conducted were the air space to be filled with material of relatively high conductivity such as fire brick.

Fire brick with a minimum conductivity of 6.7 B.t.u. per sq. ft. per hr. at 400 deg. fahr. increases in conductivity to 13.3 B.t.u. at 2400 deg. fahr. Insulating brick averages about 12 times as effective in retarding the passage of heat as the refractory. The low conductivity of this insulating material is due to the fact that it contains a volume of as much as 85 per cent of infinitesimal air cells which effectively break up the heat waves. The term "infinitesimal" is used advisedly as it is estimated that there are from forty to fifty million of these cells in each cubic inch of the natural rock. Being practically pure silica (SiO_2) the material has a high melting point, 2930 deg. fahr., as determined by the United States Bureau of Standards. This permits its use as insulating material in practically all types of heated equipment. It is recommended strictly as an insulating material, however, and in no case should the refractory linings be eliminated, principally due to the fact that insulating materials are not physically constituted to withstand a great deal of abrasion. On the other hand the crushing strength is unusually high, averaging over 400 lb. per sq. in. (*Iron Trade Review*, Jan. 8, 1925, pp. 151–152)

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

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The United States Air Mail Service

THE Congress of the United States has, on the whole, been singularly indifferent to the significance of aircraft in transportation and to the importance of developing the commercial use of airplanes and airships in the United States. Notwithstanding the failure to secure any such legislation for the Federal control of flying as is generally conceded to be an essential prerequisite of the incursion of private enterprise into that field, however, this country has been the scene of an experiment in commercial flying which is without a peer of its kind.

To compare such wholly different things as the transport of passengers and the transport of mail is not an easy matter, but it can at least be said without qualification or reservation that the Air Mail service between New York and San Francisco, operated by the Post Office Department, is in every way the most important, most reliable, and most efficient operation in the aerial transportation of mail as yet undertaken anywhere in the world. The route is the longest served for any purpose whatever by aircraft operating continuously under a single management. The service has to its credit a greater number of airplane-miles of flight since its inauguration than any three private air lines in the world combined. It was on the New York-San Francisco Air Mail route that there was first demonstrated the possibility of maintaining with airplanes a reliability and regularity of adherence to schedule comparable with those of land or sea transport. Finally, and most important of all, it was on that route that regular night flying on a fixed schedule was first attempted, and the experiment of night operation has now been carried on for more than six months with such success that the exceedingly mountainous region between New York and Cleveland, as well as the simpler country between Cleveland and Rock Springs, Wyoming, is shortly to be covered during the hours of darkness.

The Air Mail stands out among undertakings in aerial transport because it is primarily transport, while most of the others have been primarily aerial. Put less epigramatically, that means that the officials who have operated the Air Mail, many of them coming with experience in other branches of the transportation industry or from other divisions of the Post Office Department, have realized that the airplane must stand on its own feet in competing with railroads and other existing transportation facilities, that it could claim no special exemptions and no special favors. There has been a regrettable tendency in the case of some passenger lines, a tendency naturally growing out of the great importance of aircraft in war and of the value of an aircraft industry to a nation, to insist that the airplane should be treated as something special, possessing an inherent virtue which entitles it to be forgiven irregularity of operation, dangers, and delays. The Air Mail has never proceeded on that line, and one need have neither knowledge of aeronautics nor interest in the subject to acclaim the Air Mail a success.

In one respect the success seems to have been incomplete. An energetic press agent would have been useful. Only very recently has the service begun to get any appreciable part of that publicity which is its due, and even now the business and professional men of the community, taken as a whole, seem to have an incomplete understanding of the great advantages which the Air Mail service offers them in dealing with distant correspondents. That deficiency, however, will be repaired by the passage of time. The service will come to be appraised at its full value. The value itself will be constantly increased with further experience and with growing economy of operation, and the amount of mail handled by air, both on the present route and on others to be established, will inescapably be multiplied many-fold in the years to come.

Edward P. Warner.[1]

Standardization of Symbols Used in Formulas

CONSERVATION of human brain power is a result which will be achieved by standardization of symbols used in engineering and scientific formulas, and this is to be sought by a committee just organized under the procedure of the American Engineering Standards Committee.

Whenever we learn a new mathematical principle we learn it in terms of a given set of symbols. A definite and more or less indelible impression of this principle is made in those cells of the brain where memories are stored. When we have occasion to apply the principle at a later time our memory cells bring it to the center of our attention *associated with the original set of symbols*. If the symbols involved at the time we desire to apply the principle are new, a distinct effort of the mind is required to make a change over. A certain amount of brain power is used up which would have been conserved if the application of the principle involved the same symbols as were associated with the learning of it. For instance, many engineers have learned the relation between bending moment and stress in beams in the form $M = SI/c$. It requires a definite extra mental effort to use y instead of c as the distance to the extreme fiber.

Formulas and symbols constitute the machinery used in applying brain power to scientific work. If the operation of the machinery is simplified so as to consume but little brain power, so much more is left for the scientific work itself. In medieval times this machinery and the acquisition and use of knowledge were made as complex as possible, and principles were given in anagrams or in forms which were purposely made difficult to understand. Modern methods have done away with such things and we now seek to make knowledge and science as easy to use as possible. Thus it is quite possible to multiply with use of Roman numerals, but it is so difficult to multiply XIX by MCVII that the Arabic system was adopted long ago. It is similarly cumbersome to have every textbook and paper on a given subject use a different set of symbols. For instance, a recent investigation by Committee No. 20 of the S.P.E.E., of symbols for thermodynamics of steam used by about 20 different authorities, showed use of 20 different lists. Although many agreed in some items, no two lists were wholly alike.

A number of attempts have been made to effect some sort of standardization of symbols, but none of these have been broad enough in scope to have achieved success. The scientific world is so closely linked at the present time that nothing short of international standardization can accomplish a lasting result. Textbooks in English, German, and French are used by most engineering and scientific workers, and mere standardization of symbols for

[1] Aeronautical Engineer, Massachusetts Institute of Technology, Cambridge, Mass. Former Chairman, Aeronautics Division, A.S.M.E.

the United States or for the English language would accomplish but little. The present project has therefore been organized along broad lines with the idea of ultimately securing international standardization.

The Society for the Promotion of Engineering Education was a pioneer in this field but the present broadly coöperative effort resulted from the initiative of the American Institute of Electrical Engineers, the Association of Edison Illuminating Companies and The American Society of Mechanical Engineers. After two years of agitation the project has been definitely organized under the auspices of the American Engineering Standards Committee with the following bodies as sponsors:

Society for the Promotion of Engineering Education
American Association for the Advancement of Science
American Society of Civil Engineers
American Institute of Electrical Engineers
American Society of Mechanical Engineers.

The International Electrotechnical Commission published years ago a set of symbols for international use in electrical engineering. This has been generally accepted and has done a great deal to simplify the work of electrical engineers. It is hoped that a similar international arrangement may be made in each branch of science or engineering which uses a set of symbols. One of the principal duties of the various committees in charge of the details of the project will be to foster such international arrangements through the American Engineering Standards Committee, which acts as the official channel of communication in all international standardization relationships. A second duty will be to encourage the general adoption of whatever lists of international symbols may be established. Some difficulty is expected in this connection. Each one of us has already learned a set of symbols and we do not like to change. Each one of us would of course prefer that the international symbols be those with which we are personally familiar. This of course cannot be done, and a great many compromises must be made. Manufacturers of bolts, nuts, screws and other machine elements have been very broad-minded in accepting standardization projects even at considerable sacrifice in the discarding of things previously in use, because they realized that there would be financial gain in the long run. It is to be hoped that the scientific fraternity will be equally broad-minded and will be willing to make similar sacrifices for the sake of the mental gain which will be secured in the long run.

The goal to be attained is the use of an internationally standardized set of symbols for a given subject in every textbook and every scientific paper concerning it published anywhere in the world. Then a reader of any nationality will know exactly what the symbols mean without any expenditure of mental effort, and can devote his entire attention to the subject-matter of the paper itself.

SANFORD A. MOSS.[1]

Corrosion

THERE are many good reasons for the growing interest in the problem of corrosion. In the first place, with the enormous use of steel in modern industries and a rate of production for this country alone of the order of 40,000,000 tons of ingots per year, the destruction of property by corrosion is beginning to run into sums so enormous as to stagger imagination. Taking figures presented a couple of years ago by Sir Robert A. Hadfield on losses by corrosion and translating them into terms of dollars, it would appear that the annual toll taken by this one evil may be legitimately estimated at $900,000,000.

The second reason why engineers are working more and more on this problem is the growing conviction that these enormous losses are really entirely unnecessary and that somewhere there is a solution for it. In fact, partial solutions have been already discovered, and it is merely a question of finding a practical one applicable to ordinary engineering materials. Had chromium been as common, for example, as sand, the problem would have been solved. From the work of Brearley, Haynes, Becket, and others it is known that chromium present in steel to the extent of from 10 to about 30 per cent inhibits corrosion most effectively and makes steel resistant not only to ordinary atmospheric influences but even to such powerful corrosive agents as boiling sulphuric acid. The trouble is that chromium is one of the uncommon though not rare elements, and the cost of high-chromium steel is entirely too high for mere ordinary uses.

It has also been found that small amounts of copper, say, 0.5 per cent, materially increase the resistance of steel to mild corrosive agencies. Investigators are also obtaining more and more information on such matters as corrosion in boilers and condensers, and some work has been successfully done abroad in the direction of preventing corrosion of boiler tubes by establishing an electrical potential opposite to that producing the corrosive effects.

Furthermore, more and more material is being collected on the effect of protective coatings and paints where such can be applied, as, for example, in bridge work. A railroad in the United States has developed a very simple method for giving a protective coat to its rails, which is done at very small cost and is said to give appreciable results.

Of late considerable work has been done on the production of pure electrolytic iron, "pure" in this case meaning something of the order of 99.99 per cent metallic iron, the remainder being apparently occluded hydrogen. Such iron, which through the exigencies of the process itself is produced in tube form, appears to be highly resistant to corrosion and may become commercially important as soon as the details of manufacture are properly developed and provided the subject of costs finds a satisfactory solution.

By employing microscopic investigation of corroded metal together with chemical analysis, an increasingly clear insight into the mechanics of corrosion itself is being obtained, and apparently it is merely a matter of time until phenomena of corrosion are properly classified and a remedy for them found either in the methods of producing materials not subject to corrosion or in varying the conditions of service so as to inhibit corrosion entirely, or, at least, materially delay it.

From this point of view it may be of interest to see what the chemical industries have done. Having to handle corrosive liquids such as diluted acids, alkalies, etc. the chemical industries were particularly interested in finding materials that would give good service without being excessively expensive. Among such materials which are giving excellent service now may be mentioned the high-silicon irons known under the trade names "duriron," "tantiron," etc. Only a few of these are applicable to constructions used in mechanical engineering, but they indicate what has been done and give an insight into what can be done with proper application. One of the great difficulties of many constructions in mechanical engineering is that they are exposed simultaneously to corrosive agencies and high temperatures, so that oxidation or scaling goes on simultaneously with other forms of corrosion, such as, for example, in the case of grate bars. It has been found, however, that a suitable treatment, such as impregnation of the surface skin with aluminum or chromium, which form alloy films with the iron, increases the life of the article to quite a material extent. This is somewhat in line, though done at higher cost, with similar applications of lead, and especially zinc, to protect metal surfaces, and differs from them in that it works at very much higher temperatures.

It should be clearly remembered, however, that, contrary to the somewhat general impression, iron alloys are not the only ones subject to corrosion, and, for example, the investigation of the U. S. Bureau of Mines on corrosion due to mine waters has shown that many brasses and bronzes stable under ordinary atmospheric conditions rapidly corrode when exposed to more powerful agencies.

The foregoing would show that the problem of corrosion has already become one of very noteworthy economic importance and that it is being attached vigorously and from many angles. It has been the experience of the past that when such a problem becomes really important, some solution for it is usually found, and this solution may be expected to happen in the case of the "demon corrosion," as it is fondly called by makers of non-corrosive materials.

[1] Engineer, Mechanical Research Dept., General Electric Co., West Lynn, Mass. S.P.E.E. and A.S.M.E. representative on Sectional Committee for the Standardization of Scientific and Engineering Abbreviations and Symbols.

Advancing Science

OVER four thousand workers in science, from all parts of the country, gathered in Washington from December 29 through January 3 for the largest meeting yet held of the American Association for the Advancement of Science. They represented all branches of science whose achievements were presented, discussed, and recorded in the meetings of forty-six national societies that met in affiliation with the main body.

The meeting was the occasion for highly significant utterances by President Coolidge, Secretary Hughes, and Dr. Charles D. Walcott, retiring president of the Association. Both President Coolidge and Secretary Hughes deplored the fact that eminent scientists are called upon to serve the Government without adequate recompense. President Coolidge pointed out the grave responsibility of science for the future of man and Secretary Hughes dwelt on the fact that science known no political boundaries and points the way to peaceful coöperation between nations. Excerpts from their addresses follow.

I welcome your great gathering to Washington. You represent the interests, the forces, and the endless activities which literally from day to day are conquering new domains and adding them to the imperial realm of human knowledge. The future of civilization is well-nigh in your hands. You are the wonder workers of all the ages; the marvels of discovery and progress have become commonplace simply because their number has paralyzed the capacity of the mind for wonderment. Those of us who represent social organization and political institutions look upon you with a feeling that includes much of awe and something of fear, as we ask ourselves to what revolution you will next require us to adapt our scheme of human relations.

But we know that you are animated by a profound purpose to better the estate of men. We are confident that society will somehow devise institutions capable of adaptation to the changed circumstances with which you are surrounding the business of living in our world. We trust ourselves to you. Perhaps with some doubt as to what you may finally do with us and to us, but at least with firm convictions that your activities will save life from becoming very monotonous. And besides, we realize that if we did not give you our confidence you would go ahead without it.

It is a wonderful thing to live in a time when the search for truth is the foremost interest of the race. It has taken endless ages to create in men the courage that will accept the truth simply because it is the truth. Ours is a generation of pioneers in this new faith. Not many of us are endowed with the kind of mental equipment that can employ the scientific method in seeking for the truth. But we have advanced so far that we do not fear the results of that process. We need truth; and we turn to you men of science and of faith, eager to give you all encouragement in your quest for it.—PRESIDENT COOLIDGE.

We are deeply interested in the promotion of peace. But there are only two methods by which we really may assure peace. The one is the long and difficult process of drying up the sources of controversy, of getting rid in some amicable fashion of actual causes of difference. The other is by developing new and enlarged conceptions of national interests and thus avoiding the strife due to narrow and artificial concepts, by mutual appreciation of the advantages which will accrue by pursuing paths of peace and by an adjustment of our international relations more in sympathy with the methods and revelations of science.

I am in hearty sympathy with those who would make aggressive war a defined crime, but such definitions, like other legal concepts, in order to be effective, must be sustained adequately by sentiment, and we make the most rapid progress as we convince the practical judgment that unnecessary resort to force is a stupid blunder. It is your work that points to the benefits of peaceful coöperation that are within our grasp. Science, it is true, forges the weapons of war and constantly develops new and more terrible instruments of destruction. But she is far more eloquent as she points to the wastes of strife, the retarding of progress and the vast opportunities which are open to industrious peoples if they are able to abandon their mutual fears and destroy the artificial barriers to community of enterprise.

We should think in terms of the coöperation of peoples and not simply of governments. Science knows no political boundaries; she recruits her conquering chieftains from all climes and races. It may be an Austrian monk revealing the secrets of plant inheritance; or a New Hampshire farmer's boy who learns to fashion instruments of the utmost delicacy and precision; or a Serbian herdsman taking youthful lessons in communication by listening through the ground; or a Japanese devotee of medical research isolating and cultivating micro-organisms. In this field all are co-workers and pride is not of race or of tradition but of achievement in the interest of humanity.—SECRETARY HUGHES.

Dr. Charles D. Walcott emphasized the great progress of science but pointed out that the conquest of the unknown and the unprogressive doctrine of "apostles of systematized ignorance" is still far from complete. He urged coöperation between all branches of science in solving the problems incident to the conservation of our national resources and in educating the great masses of humanity in the scientific method of thought and action.

The Engineering Section of the A.A.A.S., of which Dr. A. E. Kennelly is chairman, held two sessions. Alfred D. Flinn, Director of the Engineering Foundation, gave an address at one of the sessions in which he stressed the importance of engineering research in advancing the profession of engineering and outlined the purposes and procedures of the Engineering Foundation. The second session was addressed by Maj.-Gen. William A. Black and Senator Howell, of Nebraska, who dealt respectively with the engineer in public service, and the engineer in legislation.

Dr. Michael Pupin, Professor of Electromechanics at Columbia University, was selected as president of the Association for the next year. He succeeds J. McKeen Cattell, editor of *Science*, who will deliver the retiring president's address at the meeting of the Association in Kansas City in December, 1925.

Investigation of Engineering Education

IN 1923 the Carnegie Corporation granted $108,000 to the Society for the Promotion of Engineering Education for an investigation which should be "directed to a study of the objects of engineering education and the fitness of the present-day curricula." This general pupose has been developed into specific objectives and procedures to achieve them which have been stated by Charles F. Scott, Chairman, F. L. Bishop, Secretary, and William E. Wickenden, Director of the Board of Investigation and Coördination of the S.P.E.E. in the January, 1925, issue of the *Journal of Engineering Education*. An abridgment of the statement follows:

The central problem of the investigation is believed to be the determination of the fundamental purposes and functions of the engineering colleges in the fields of education, industry, professional life, and public service.

A clear conception of these functions is essential if the colleges are to solve many of the specific problems which confront them. The investigation is therefore being focused upon the central problem and its numerous divisions are planned with this as a guiding principle. It is proposed that the three-year period of the Carnegie grant shall be devoted primarily to the investigative stage of the undertaking. It is expected that this will be followed by, and to a considerable extent be concurrent with, a coördinated effort on the part of the colleges to adjust their curricula and educational methods so as to serve their proper functions most effectively.

The preliminary reconnaissance seems clearly to indicate that the future course of the engineering colleges will be an orderly and intelligent readjustment of their educational programs, rather than a revolutionary change. The investigation is being shaped to this end. Furthermore, it appears that the breadth and diversity of engineering activities are such as to make undesirable the standardization of engineering courses or their reduction to a uniform plan.

Since the present stage of the project is primarily investigative, the policy has been adopted of first gathering the facts bearing upon the situation. A group of coöperative agencies including the Faculty Committees, the United States Bureau of Education, engineering societies and other bodies, are now engaged in gathering the facts.

The National Industrial Conference Board is conducting studies of the occupational demand and opportunity for graduates in industry as a coördinate undertaking. These studies have reached a well-advanced stage.

As a supplement to their contribution to the general program, many of the Faculty Committees are studying the distinctive problems pertaining to their own institutions.

It is planned to interpret the evidence gathered in the investigation in collaboration with special committees of the Society and to present the results in the form of a report or reports.

OBJECTIVES OF THE INVESTIGATION

I—*It is the intention to clarify the educational functions and responsibilities of the colleges of engineering:*

a To define the educational functions of the colleges of engineering.

It is the purpose to determine to what extent the program of engineering education serves a *collegiate* type of training employing science and technology as its principal media; and to what extent it provides a *professional* type of training comparable with that in medicine.

b To indicate how engineering curricula may be coördinated more effectively with the needs of industry and the requirements of engineering practice.

It is the desire to determine how adjustment between the need for specific training on the one hand and for broad training on the other may be effected so as to provide to a reasonable degree for the immediate demands upon graduates in their earlier positions, and at the same time to provide the foundation for advancement to broader duties in the industrial and professional world and in public life.

c To determine whether or not it may be desirable and practicable to vary the extent of training in engineering to accord with

(*a*) the capacities of students, and

(*b*) the requirements and opportunities of industry.

Consideration will be given to a more elastic educational program

than is now in effect, in order to determine whether or not both the duration and content of engineering courses may be varied to suit differences in the capacities of students and to fit more closely the requirements of industry for technically trained men.

d To determine what responsibilities the colleges should assume for the further training of graduates.

It is the purpose to ascertain the need among graduates for more extended training in special fields than that provided by their undergraduate courses.

II—*It is the intention to establish guiding principles for the content and arrangement of curricula and the improvement of teaching:*

a To formulate criteria for selection of the content of the scientific, technological, economic and "cultural" subjects of instruction, and for the proportioning of these major divisions of curricula.

b To promote more effective articulation of instruction in the various subjects which make up an engineering curriculum.

c To indicate means of more valid correlation of instruction in engineering with the technical and economic problems of engineering practice.

d To ascertain directions to improve methods of teaching in engineering colleges.

III—*It is the intention to consider in what ways problems relating to engineering students, graduates and teachers may be dealt with more effectively:*

a To determine what steps may be taken to insure the entrance of properly qualified students.

b To determine what measures may be taken to deal more effectively with the problem of eliminations.

c To ascertain the methods which may best be used by the colleges to facilitate the obtaining of suitable employment by their graduates and to promote their further development.

It is the purpose to canvass the economic demand for engineering graduates through the coöperation of the industries and professional organizations.

d To indicate how methods of recruiting and developing engineering teaching staffs may be improved.

IV—*It is the intention to examine the practicability and possible benefits of closer group relationships among the colleges and with professional organization of engineers:*

a To indicate the extent to which further development of group action by engineering colleges is desirable, and to point out how such action may be effected.

b To determine how the engineering colleges and the professional organizations of engineers may effect a closer association for the mutual benefit of engineering education and the profession of engineering.

V—*It is the intention to make an analytical comparison of the organization and practices of engineering education in Europe and America:*

a To compare the positions occupied by the engineering colleges in the educational systems of their respective countries.

b To compare the educational practices of the several groups of institutions relative to admission standards, teaching and examination methods, curricula, the development and status of teachers, and the like.

c To compare the relations of the several groups of institutions to the industrial life, the governmental and public services, and the professional organizations of engineers of their respective countries.

PROCEDURES OF THE INVESTIGATION

The several phases of the investigation are being carried out in the following steps:

1 Survey of the situation.

This fact-finding process is now in progress through coöperation of committees of the colleges, the United States Bureau of Education, the Joint Advisory Committee with the National Industrial Conference Board, the engineering societies, and other agencies. The collection of the information is being carried out through a number of definitely formulated projects.

2 Analysis of the facts and their presentation in systematic order.

3 Interpretation of the evidence.

4 Experimentation, where desirable, upon the basis of the facts ascertained.

It is contemplated that experimental projects will be formulated and invitations to conduct them extended when sufficient evidence has been gathered to indicate the basis of such experiments.

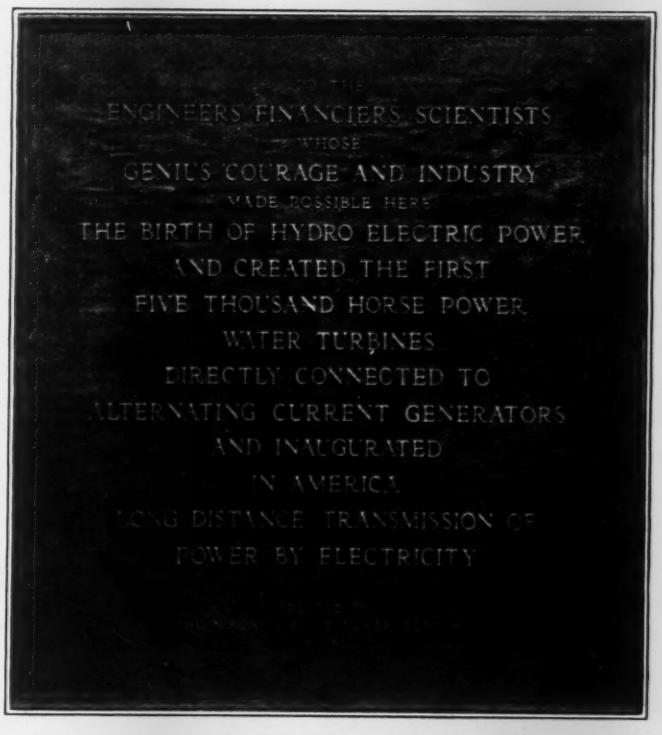
5 Presentation of a comprehensive summary of the foregoing investigative processes.

This will be in the nature of a report or reports on the initial stages of the investigation.

As the result of the investigative processes become available it is the expectation that the general project will develop naturally into a concerted effort on the part of the colleges of engineering to effect the needed adjustments of their curricula and educational methods. As the emphasis shifts from investigation to development, the initiative is expected to pass more and more to individual institutions. There should be a period of study and discussion of the situation by faculty committees and in faculty meetings, from which conclusions should be reached and plans for action formulated. As the plans are put into effect, their results should be observed. It is not the aim to bring the project to a definite stage of conclusion, but rather to prepare the way for a continuing process of educational inquiry and adjustment, and to develop within the society's organization the means of making the coöperation of the colleges in this process effective.

Bronze Tablet Commemorates Niagara Falls Power Pioneers

A BRONZE TABLET commemorating the pioneer engineers, financiers, and scientists of the Niagara Falls Power Company was unveiled at noon on January 3, 1925, at the portal entrance to Power House No. 1, wherein were installed thirty years ago the world's first 5000-hp. water turbines directly connected to alternating-current generators. The time of the unveiling of this memorial tablet was a fitting one, for it marked the completion of the latest Niagara power project on the American side of the river. In this new power house we find again the world's largest turbines, three gigantic water wheels each capable of delivering in excess of 70,000 hp. Thirty years ago the engineering and scientific world wondered where and how the fifteen thousand available horsepower of Niagara's energy could ever be utilized. Today the American



BRONZE TABLET ERECTED IN 1924 ON LEFT WALL OF PORTAL ENTRANCE TO POWER HOUSE NO. 1, AS A TRIBUTE TO THE POINEERS OF THE NIAGARA FALLS POWER CO. OF 1886

generating system at Niagara constitutes a pool of power from which western and central New York State draw nearly half a million continuous horsepower of electrical energy to lighten labor in the home, the shop, and the factory.

The tablet is the gift of Edward Dean Adams, of New York City, for twenty years president of the Cataract Construction Company, which later grew into the Niagara Falls Power Company. The pioneer officers and directors of the Cataract Construction Company in addition to Mr. Adams were: Francis Lynde Stetson, Edward A. Wickes, William Birch Rankine, John Jacob Astor, John Crosby Brown, Walter Howe, Joseph H. Larocque, D. O. Mills, George S. Bowdoin, Charles F. Clark, Charles Lanier, Leith of Fyvie, and Frederick W. Whiteridge. Mr. Adams and Mr. Lanier are the only living members of the group.

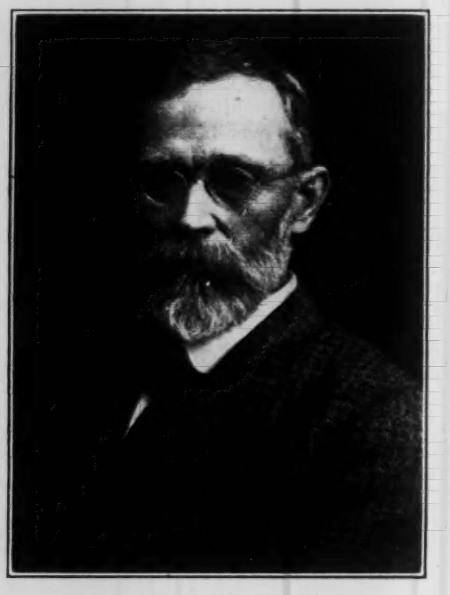
Among those who attended the ceremonies of the unveiling were Mr. Adams, Dr. W. F. Durand, President of The American Society of Mechanical Engineers, Dr. Arthur E. Kennelly, Past-President of the American Institute of Electrical Engineers, Charles F. Rand, Past-President of the American Institute of Mining and Metallurgical Engineers, Gen. Guy E. Tripp, Prof. Charles F. Scott, and many of the present officers and directors of the Niagara Falls Power Company.

A luncheon was tendered Mr. Adams and his party at the Red Coach Inn by the executives of the power company, at which appreciation of his gift of the tablet was sincerely expressed.

M. L. Holman, Past-President of the A.S.M.E., Dies at the Age of Seventy-Three

M. L. HOLMAN, retired mechanical engineer and former water commissioner of St. Louis, Mo., died on January 4, 1925, at his home in that city. Mr. Holman was born in Oxford County, Me., on June 15, 1872. He was graduated from Washington University in 1874 with the degree of A.B. The honorary degree of A.M. was conferred on him by his alma mater in 1905.

He began his professional career in the offices of the superintendent of architecture of the United States Treasury Department. In 1877 he became an assistant engineer in the St. Louis Water Works, and ten years later was appointed commissioner, in charge of the entire water system of the city. Mr. Holman immediately took up the work of extending and modernizing the system, the city expending for this purpose about $10,000,000.



M. L. HOLMAN

During the twelve years that he held this office, he caused to be installed a new low-service pumping plant and six large settling basins, and extended an intake to the main channel of the Mississippi River. He installed new pumping stations, equipped with up-to-date machinery, which saved the city 80 per cent of fuel. He introduced the system of paying a bonus to builders for high efficiencies in pumping engines. It was under Mr. Holman's administration as commissioner that a division of the water distribution was made, so that a part of the city was supplied from one point and the balance from another. He also inaugurated the experiments in water sedimentation and purification by the aid of chemicals. In 1897 he visited Europe for the purpose of making a study of foreign filtration systems.

He served on the Board of Public Improvements of St. Louis, which has charge of the public engineering and structural work of the city, and as Chairman of the Committee on City Lighting had charge of the undergrounding of the electric wires, and the preparation of the specifications and letting of contracts for the lighting of streets, alleys and public buildings.

Mr. Holman's success in his administration of the St. Louis Water Department established him as an authority in this field, and he was often called for consultation regarding similar problems in other cities. He served on the Board of Appraisers of Denver, which determined the value of the water system of that city and fixed schedules of water rates.

Upon resigning from the public service Mr. Holman was for five years general superintendent of the Missouri Edison Electric Co., and in 1904 became senior member of the firm of Holman & Laird, consulting hydraulic and mechanical engineers of St. Louis. This enterprise was abandoned upon Mr. Holman's retirement.

Mr. Holman was actively interested in The American Society of Mechanical Engineers, serving as vice-president of the Society in 1894–1896 and 1903–1905, and president in 1908–1909. He was aslo a member of the American Society of Civil Engineers and vice-president of that organization from 1905 to 1906. He was an honorary member of the American Water Works Association and belonged to the Engineers' Club of St. Louis.

Development in Fuels Engineering

IN AN ARTICLE entitled "What Price Railroads?" in the *Outlook* of January 21, 1925, Hugh H. Hughes, Director of Markets in the State Department of Agriculture of Minnesota, points out that in 1923 out of 50 million cars loaded on the railroads, 9½ million carried coal. It would appear, therefore, that roughly 18 per cent of the total freight carried by our rail transportation system was fuel used by the country, not to mention the enormous quantities of oil which also had to be transported partly by tank car and partly by pipe lines. Further, from the same article it would appear that no other class of products required as many cars for its transportation as coal, there being only 2¼ million cars for grain and grain products, 2 million for livestock, and 2½ million for ore.

All of this coal was utlimately burned in some kind of furnace, locomotive, steamboat, power plant, household, gas producer, or blast furnace, and it is primarily the efficiency of these furnaces which determine the volume of standard fuel required. When we consider the enormous tax that coal haulage imposes on the capacity of American rails, it is difficult to escape the conclusion that efficiency in fuel utilization is one of those economic factors that contribute mightily to the progress of American industrial life. Developments in fuel engineering, therefore, becomes one of those factors which ought to be, but unfortunately are not, of interest not only to the engineer but to every man, woman, and child in the country, as all of them have to "pay the freight" in the form of higher or lower costs of transportation, goods, food, and rents.

From the survey presented elsewhere in this issue by H. W. Brooks of the U. S. Bureau of Mines, it would appear that while in the past year there have been no sensationally new discoveries or inventions, there was unquestionably a good deal of healthy progress made. Not only that, but evidence is brought forward to show that industrial concerns are becoming less and less averse to trying out novel methods, provided there is good reason to believe that they will result in reducing costs of production. One concern tried out on a large commercial scale a complete gasification plant, another one a commercial-scale experiment of a new process of low-temperature coal carbonization, and a third big company installed superstokers. Air-heater installations, stokers on water-cooled boiler furnaces, stokers on locomotives, large pulverized-fuel installations with new fin-type water-cooled furnaces, etc. are all indications that possibly under the spur of sharpened competition, together with high costs of fuel, manufacturers are no longer thinking that what was good for their fathers is good enough for them.

A rather significant fact is apparent from the review of outstanding developments during 1924 as given by Mr. Brooks. At all times there have been men who have dreamed of some startlingly new effects of coal utilization, but hitherto all such schemes have either remained in the realm of fancy or have taken years and years for development.

In the last ten or fifteen years, however, such a large amount of data as to the chemistry of fuels and their structure has been accumulated that schemes which would have formerly appeared daring can now be carried out rapidly and with sufficient promise of commercial success to be undertaken by commercial concerns. To this class of developments belong the conversion of coal into oils, a problem on which intensive and apparently successful work is now being done in Germany, France and England, and modification of the pinking point of motor gasoline by the addition of such inhibitives as tetraethyl of lead.

There is no question, therefore, that Mr. Brooks is fully justified in the conclusion which he reaches that "Ever-increasing interest of financiers and industrialists in fundamental research coupled with the markedly improved business conditions which usher in the new year portend a still further stimulation in fuels engineering during 1925."

Book Reviews and Library Notes

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Frederick W. Taylor

FREDERICK W. TAYLOR: FATHER OF SCIENTIFIC MANAGEMENT. By Frank Barkley Copley. Illustrated. Harper and Brothers, New York, 1924. Cloth, 6 by 9 in.; vol. 1, 467 pp., vol. 2, 472 pp., illus.; $10.

ALL who knew "Fred" Taylor well will recognize this biography as a most excellent piece of work. It is clear that the author has had access to abundant material and that he has delved into it thoroughly and conscientiously, with the sole object of presenting a true and lifelike picture of his subject; in no biography that I know of has more complete success been attained.

No one who is in any way or in any degree concerned with knowing what has happened to American industries and how it has happened since Taylor went to the Midvale Steel Works in 1878, can fail to find these volumes absorbingly interesting and extraordinarily informative.

This is not a mere colorless catalog of achievements, great and far reaching as those achievements were; not alone Taylor himself but many other outstanding men connected with industrial affairs are here presented to view in what to most of us is a new light; some to their high credit and some quite to the contrary. Indeed, the success attained by a number of famous men in industrial affairs is clearly seen to be necessarily attributable to causes other than ability as industrial managers for of such ability, it is made clear by this record, they had practically none whatever, not only when judged by present-day standards, but by the standards of their day. This is only incidental, however, for this is essentially a life of Fred Taylor, and others are brought into it only as brush strokes needed to complete the picture of that unique, talented, and many-sided character.

Taylor is here shown to have been reared in a refined environment by parents both well and broadly educated. His entry into industry is shown to have been almost purely accidental, though he early exhibited a talent for invention and for systematic ways of doing things.

His first employment was (I feel bound to say, unfortunately) in a place where things were pretty rough, where the only discernible philosophy was, on the one side, to drive, and on the other, to resist that driving; where gross profanity and all that it connotes was thought to be a necessary element in a workshop, as it is said to be in driving mules. Taylor, young and impressionable, not only adopted it but deliberately cultivated it, mainly for shop use, ignoring the plain fact that many of the most successful managers of that day, as of this, never used it nor ever allowed themselves under any circumstances to exhibit any evidences of anger or of serious emotional disturbance.

Most of us have had the idea that the Taylor "system" was developed and put in practice from previously-thought-out plans, much as an office building or a factory is built. It is here made plain that the system was developed by a step-by-step process, each step being dimly, if at all, foreseen, but finally perceived to be more or less a necessity to hold the ground attained by preceding steps. Just here Taylor's remarkable persistence and indomitable courage enabled him to go on and on to magnificent accomplishment where others, perhaps equally well equipped in other respects, would have been discouraged and quit.

He began by trying to get men working in a machine shop to do more work; found their knowledge exceeded his own; built up his knowledge of the work; found he could not go very far because the management was faulty or practically non-existent; started in and, step by step, developed a science of management; found the accounting, especially the cost accounting, blocked his way by its inadequacy and stupidity; learned accounting and developed a real system of industrial accountancy.

He started to climb a high and difficult mountain; climbed one step at a time, never thinking of giving up or even resting himself so long as his strength lasted. The top of that mountain is not yet clearly visible—it will probably be difficult to determine when, if ever, it is quite reached—but to Taylor belongs the credit of showing that it can be climbed and how it can be climbed. There were those who appreciated and helped him—William Sellers, James Mapes Dodge, Henry R. Towne—all men of outstanding achievements, partly because they could understand the work of others and were above being jealous or envious of it. Besides these outstanding men in civil life, General Crozier, Chief, Ordnance Department of the U. S. A., and Admiral Caspar F. Goodrich, of the Navy, did all that was humanly possible to secure, for their respective departments, the benefits of the new system, and Taylor gave his services to them in the public interest, I understand, without charge.

Whatever Taylor did he literally did with all his might. Whatever seemed to stand in his way even for a minute he attacked, usually with a vigor and vehemence that made him, unnecessarily, many enemies, not alone among workingmen but among employers as well.

But there was no guile in him; whatever he did he believed in with all his soul, and whatever he believed in he did with the same absorbing devotion; utterly unable apparently to understand the world's capacity for passive and active resistance to innovators.

Workingmen, generally, in and out of unions misunderstood him, and the vast majority of employers resented his unsparing criticisms of their management. To many of them Scientific Management and the Taylor System are still anathema. No one can say in what degree this is due to the bludgeon methods of Taylor and some of his disciples, but much of it is undoubtedly. The biographer has clearly recognized this and revealed it.

Then, too, a little more familiarity with fundamental economics would have spared this heroic personage a good deal of effective opposition. He was wrong as to some of the results he anticipated from his work, and failed to realize the fact that a very large proportion of workingmen these days do far more reading of journals that are independent of "counting-room influence" than the journals generally read by employers; and devote more attention to the study and discussion of fundamental economic principles; principles which, to disregard, is a great mistake, and is responsible for most of our industrial and business difficulties.

An important share of Taylor's difficulties at Bethlehem are shown to have arisen from the fact that a number of directors of the company were landlords in Bethlehem and imagined their personal interests as landlords were threatened by Taylor's efforts to get given quantities of work done by fewer workers. They actually thought Taylor was going to depopulate Bethlehem and make rent payers scarce. Yet when a hard-headed, successful

millionaire manufacturer wrote Taylor urging a solvent for that difficulty, Taylor spurned him and said quizzically, "There is a man even crazier than I am." Repeatedly Taylor avowed his belief that his system would, of itself, solve all industrial and accompanying social problems. Whereas the workers knew by hard experience that, for example, the introduction of steam power and labor-saving machinery—increasing the productive power of workers far more than any system of management could—had brought them only that which they had fought for through unions and otherwise; as witness the struggle to abolish the sweat shops long after the introduction of power-driven sewing machines and the appearance of Hood's "Song of the Shirt."

To decry or oppose labor-saving machinery or improved systems of industrial and business management is of course futile and foolish, but not for the reasons Taylor thought it was; and hence much of what he said about the social effects of his work was based upon a wrong premise, did not ring true, and workmen in general more or less clearly perceived this. It did not square with their experience, nor with the history of "the labor movement" reaching far back to the days of the ancient guilds and beyond. This tended to confirm their suspicion that Taylor management was simply another scheme to make workers turn out more work for the same or even less wages. They misunderstood and were not aware that Taylor believed and intended that his system would and should benefit the workers as well as employers. Out of this misunderstanding grew Taylor's reiterated and bitter denunciation of workmen for general "soldiering," a charge which had absolutely only one effect, that effect being increased and more effective opposition to the introduction of the Taylor system. Taylor was made to feel very keenly mankind's intolerant and shortsighted attitude toward those who would disturb the established order; but this antagonism was increased by such things, for example, as his emphatic condemnation of tool makers as "humbugs and frauds," utterly failing apparently to appreciate the fact that thorough study of the best possible design of special tools and putting into them the best allowable or attainable workmanship, had been and still is the most important single factor in establishing and maintaining our preëminence in low-cost interchangeable manufacture of such things as sewing machines, watches, small arms, typewriters, and innumerable others.

The episode of high-speed steel is treated in an interesting way, but the fact is not brought out that Taylor, before applying for a patent, addressed letters of inquiry to all the leading steel makers here and abroad, asking them if they made, or knew of any one who made, a steel which could be heated to a white heat—"a dripping heat"—without injury to its cutting qualities.

They all said they knew of no such steel, and yet, when the validity of the Taylor-White patent on this steel was finally tested in the courts, it was invalidated on the ground that such steels had been made and used for years—a striking instance of a court's decision entirely at variance with common knowledge and informed conviction. Taylor and Maunsel White will always be credited as the real inventors of high-speed steel, as they really were, the courts notwithstanding.

There are those who think that Taylor and his work are more highly esteemed abroad than here. If that is true, may it not be because abroad they judge by the carefully considered writings of Frederick W. Taylor, whereas here what he wrote is read with stuff between the lines composed largely of violent methods and violent denunciations.

But these things will pass away. The public will forget them or will clearly distinguish between them and the real constructive work; much as Taylor's biographer has done with such consummate skill and good judgment.

For perfectly good reasons, no doubt, the full story of what Taylor did for The American Society of Mechanical Engineers during his term as its president is not revealed in these volumes nor elsewhere. That it was a critical period in the career of the Society had been perceived by others and some remedial steps had been taken, but Taylor threw himself wholeheartedly into the work, allowed nothing to stand in his way, and brought about, mainly by his own efforts, though not without assistance from others, a complete reformation in the Society's methods of administration, securing from the Council the needed authority for a small committee, of which he was chairman, to make the necessary changes in personnel.

The full story would be of interest chiefly, of course, to the Society's membership, and some day perhaps it ought to be revealed in justice to Taylor and to certain of his associates and supporters of that time, most of whom, like him who took the leading part, have disappeared from the scene of action.

FRED J. MILLER.[1]

Industrial Coal-Purchase, Delivery, and Storage

INDUSTRIAL COAL: Purchase, Delivery and Storage. A Report of American Engineering Council. Ronald Press Co., New York, 1924. Cloth, $5^3/_4 \times 8^1/_2$ in., 419 pp., $5.

THE report of the American Engineering Council on Industrial Coal, Purchase, Delivery and Storage, is probably the most complete survey of these phases of the American coal industry with which it deals so far published, and is well worth the careful study of all persons interested in those industries in which coal plays an important part.

The most important facts brought out in this report are:

1 The coal-mining industry is suffering from the effect of poor load factor due to the demand for coal being much greater in the fall and winter than in the spring and summer.

2 The railroads are compelled to haul the bulk of their coal tonnage in those months when their equipment is most needed for other commodities, and when due to weather conditions the cost of handling freight is from 40 to 50 per cent higher than in summer.

3 Coal can be most advantageously stored by the consumer at or near the point of consumption.

4 The cost of storing coal by the consumer varies with local conditions from $0.50 to $1.50 per ton.

5 Consumers are now storing about 6 per cent of the annual coal production for the purpose of safeguarding their continuity of operation. (This quantity apparently, in the opinion of the consumers, being sufficient to cover their requirements in this respect.)

6 If consumers would store in the slack months 9 to 10 per cent of the coal production over and above the quantity which they are now storing to protect their own interests, the mines would be able to operate steadily throughout the year.

Based on the above facts, the Committee recommends

1 That all coal consumers purchase their coal on annual contracts for yearly requirements with a provision for delivery in equal monthly allotments;

2 That consumers provide storage facilities to enable them to accept delivery of their annual requirements of coal in equal monthly installments.

If the above recommendations were universally carried out, undoubtedly

The railroads would make more money
The coal operators would make more money
The miners would make more money
The consumer would spend about $1.00 per ton on coal put in storage.

Maybe

The railroads would reduce rates
The coal operators would reduce prices
The coal miners would accept a cut in wages.

If they did any one or all of these things,

The consumer might get his dollar back.

If they did not,

The consumer would be out his dollar, and be a philanthropist.

If this book inspires some one to offer a plan whereby the railroad, the coal operator, and the coal miner can be induced to reduce their combined charges to such an extent that the consumer who stores his coal will get his dollar back, it will go down in history as

[1] Past-President A.S.M.E.; Member of the Pennsylvania Public Service Commission.

one of the most valuable contributions ever made to American Industry.

If not, it will still be an extremely valuable compilation of statistics.

EDWIN B. RICKETTS.[1]

Books Received in the Library

BOOK OF THE LOCOMOTIVE. By G. Gibbard Jackson. Longmans, Green & Co., London and New York, 1924. Cloth, 5 × 8 in., 244 pp., illus., colored plates, $2.

Records the history of the British locomotive, from Murdoch's model of 1784 to the mammoth engines of today, describing the advances made by various designers and showing the gradual evolution very satisfactorily. Written simply and without great technical detail, it is suited to non-technical readers as well as to those with special interest in the subject. Many illustrations, including some in colors.

CE QUE TOUT AVIATEUR DOIT SAVOIR. By Andre Lainé. Gauthier-Villars et Cie., Paris, 1924. Cloth, 5 × 8 in., 173 pp., illus., diagrams, 12 fr.

A convenient handbook for aviators, prepared by an experienced instructor and adapted to the official program of instruction in military aeronautics of the French Government. Treats of mechanics and aerodynamics; the construction, maintenance and proving of airplanes; the motor and propulsion system; atmospheric phenomena and their consequences for the aviator; and instruments. These subjects are covered concisely, with special reference to the information most needed by the aviator.

CONFÉRENCES SCIENTIFIQUES. By Albert Turpain. Gauthier-Villars & Cie., Paris, 1924. Paper, 5 vols., illus., 5 fr. each.

In these five small volumes Professor Turpain publishes a series of lectures which he has delivered from time to time before various audiences in France. These addresses dealt with various scientific and technical matters, reviewing their history, describing their development and expounding their theory. Intended for general audiences rather than for specialists, the lectures are admirable examples of the popular presentation of technical information.

DETAILING AND FABRICATING STRUCTURAL STEEL. By F. W. Dencer. McGraw-Hill Book Co., New York, 1924. Cloth, 6 × 9 in., 511 pp., illus., diagrams, $5.

A discussion of the business of structural companies by the engineer of the Gary plant of the American Bridge Company. The author treats of the proper engineering and shop organizations, methods of handling contracts, ordering materials, making shop drawings, fabricating, inspecting and shipping steel. Structural designs and specifications are studied for bridge work, office and mill buildings, tanks, ships, etc. The practices of the various departments of structural shops are discussed in detail. A glossary of shop terms is included.

ENLARGED CALLENDAR STEAM TABLES. By H. L. Callendar. Edward Arnold & Co., London, 1924. Cloth, 6 × 9 in., 80 pp., tables, $2.50.

In response to a demand for more detailed tables at higher pressures and temperatures, the tables have been extended and rearranged on a pressure basis, as being more convenient for reference. The present issue is restricted to tables on the foot-pound-fahrenheit system. The tables for the properties of saturated steam now extend from a vacuum of 29.5 in. by intervals of 0.05 in. at the lowest pressures, to a pressure of 30 in. The table for superheated steam gives the properties from an absolute pressure of 1 lb. per sq. in. and a temperature of 100 deg. to a pressure of 2000 lb. per sq. in. and temperature of 1000 deg. Auxiliary tables have been added of some quantities of use in practical calculations for experimental work.

FUEL, SOLID, LIQUID AND GASEOUS. By J. S. S. Brame. Third edition. Edward Arnold & Co., London; Longmans, Green & Co., New York, 1924. Cloth, 6 × 9 in., 388 pp., illus., diagrams, tables, $6.

This book endeavors to place before the technical man who is not a fuel specialist, but who requires a good general knowledge of the subject, reasonably full information on all fuels of importance and an account of the scientific principles underlying gas-producer practice, combustion, etc. The application of fuels to power production is kept especially in mind by the author, and he has attempted to make his account complete enough for the requirements of engineers engaged in that task. This edition has been thoroughly revised and in part rewritten.

HOW TO SAVE COAL. By Arthur B. Allen. Published by the author, East Orange, N. J., 1924. Paper, 6 × 9 in., 23 pp., $0.25.

This pamphlet gives the householder explicit directions for the economical operation of his domestic heating plant, whatever its type may be. The author writes from experience.

ORGANIZATION AND BUDGETARY CONTROL IN MANUFACTURING. By Thomas B. Fordham and Edward H. Tingley. Ronald Press Co., New York, 1924. Cloth, 6 × 9 in., 233 pp., forms, tables, $3.50.

The successful operation of a manufacturing business depends on the organization of its personnel into an efficient body. Limitations of responsibility must be prescribed and limitation of expenditure put into effect. Back of this there must be a theory. What this theory of organization is and how it is related to the budgetary control is set forth in this book. The book has been written with the object of enabling operating executives to see more clearly the relation of the parts of an organization to each other and of the operating functions to the financial statements. The authors avoid debate concerning the merits of different types of organization or systems of control, but attempt to explain fundamental methods which will apply in all cases.

RECENT DEVELOPMENT OF PHYSICAL SCIENCE. By William C. D. Whetham. P. Blakiston's Son & Co., Philadelphia, 1924. Cloth, 5 × 8 in., 313 pp., illus., portraits, $3.

Intended as a short account of some of the important investigations now being carried on in the physical laboratories of the world, this book discusses such questions as the philosophical basis of physical science, the liquefaction of gases, fusion and solidification, solution, the conduction of electricity through gases, radioactivity, matter, space and time, and astrophysics. It is intended for students of science in general, to whom it offers a summary of work in other departments than their own, and for those without scientific training who are interested in the more important conclusions of scientific thought. The edition has been thoroughly revised, partly rewritten, and enlarged.

SAMUEL OLDKNOW AND THE ARKWRIGHTS. By George Unwin. University Press, Manchester, England; Longmans, Green & Co., London and New York, 1924. Cloth, 6 × 9 in., 259 pp., portrait, $4.25.

Samuel Oldknow, the first successful maker of British muslins, was actively engaged in business from 1781–1828. This book, which is based on a recently discovered collection of his letters, account books and other business records, is an interesting, detailed description of his career. It supplies a good description of the cotton spinning and weaving trade, shows the transition from the cottage system to the factory system, and also narrates the story of Oldknow's early experiment in community buildings. A useful book to students of the textile trade and also to those interested in industrial development.

SCIENTIFIC MANAGEMENT SINCE TAYLOR. By Edward Eyre Hunt, editor. McGraw-Hill Book Co., New York, 1924. Cloth, 6 × 9 in., 263 pp., $3.

Nineteen papers illustrating various phases of the development of the management movement since 1915, when its founder died. The articles are classified in four groups. Group one reviews the nature and achievement of scientific management, telling its history, examining the types of management, and analyzing its accomplishments, shortcomings, and obligations. The expansion of the Taylor system from the factory to the business as a whole is examined in part two, while part three treats of the significance of scientific management in stabilizing plant and industrial operations, and its bearing on security of employment. The concluding group of essays discusses the relation of owner, manager, workman, and sociologist to industry, and the relation of industrial democracy to efficiency.

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